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THE EFFECT OF CONTEXT ON THE PERFORMANCE OF
CHILDREN WITH ADHD ON A SERIES OF COMPUTERISED
TASKS AND GAMES

By

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Abstract

This thesis examines context effects in relation to the performance of children with ADHD in test and 'real world' situations. There is a wealth of empirical research that illustrates poor performance of these children on a range of cognitive measures, particularly tasks that claim to measure executive function and inhibitory control. However, anecdotal reports have suggested that while playing computer games these children display abilities that contrast sharply with empirical findings. This contrast was the basis for a series of studies using computer games and computerised tasks to investigate the performance of children with ADHD across contexts..

The first investigation (Study 1), a questionnaire study, lent support to the anecdotal reports. Parents of children with ADHD confirmed that their children were able to sit still, concentrate, pay attention and achieve higher levels of success when playing computer games. In Study 2 parents of children with ADHD were asked to discuss the features of computer games they felt were most influential in contributing to their child's interest and performance. Observations made in the Study 3 provided further confirmation that performance improves when children with ADHD play computer games; performance in terms of error making and on-task activity on a standardised test of inhibition and attention, the Conners' Continuous Performance Test II (CPT II), was significantly poorer than performance on a more 'game' like Pokémon version of the task and significantly different to the performance of typically developing children. Features of computer games that may have contributed to the observed improvements for children with ADHD were examined in four subsequent studies. These features included the addition of narrative, the addition of a points scoring system, the addition of character, auditory reinforcement and differing levels of response cost. Inhibitory performance on two commercially available games was also investigated (Study 8), and the performance of participants with ADHD

was not significantly different to that of typically developing participants. The results raise questions about current understanding of the disorder and models of ADHD, stress the need for examining contextual sensitivity of children with apparently constitutional disorders such as ADHD, and have implications for methodological design and the contexts in which cognitive abilities are investigated.

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Chapter 1

Cognition in Context: Issues concerning Epistemology

1.1 Introduction

This thesis investigates the issue of context effects on behaviour and performance and focuses on the debate concerning the distinction between competence and performance in a given setting. Theories of child development have frequently assumed that as a child grows cognitive developments occur across domains. However, research into particular aspects of development, such as the acquisition of language, has suggested that viewing such phenomena in a domain specific way might be more appropriate. This thesis will consider the arguments surrounding this issue and will examine empirical studies that look at both the performance and the behaviour of participants across contexts.

There is a wealth of research that has examined the potential impact of context on performance and behaviour for typically developing children. In order to inform understanding of the possible mechanisms influencing the performance of children across settings this chapter begins by outlining some of the literature concerning the inter-relationship between context and cognition in typical development and also considers the context specificity of children's problem solving and reasoning. The implications that these arguments have for the study of cognition and how we conceptualise children's abilities and competencies are then discussed. This literature would suggest that behaviour and performance can never be decontextualised. However, questions remain concerning the generalisability of these findings. There are many other ways in which to study the impact of context on cognition. In particular, do individual differences impact on the relationship between cognition and context? It seems likely that individual differences in characteristics such as temperament, intelligence, cognitive style, preferences, ability, disability, physiology and so on will interact to determine cognition

and therefore performance and behaviour. The potential impacts of some of these characteristics are discussed in more detail in the latter half of this chapter.

In order to investigate the potential interaction between context and individual differences on cognition this thesis investigated how context might relate to the performance and behaviour of children whose development is atypical. Recently, questions concerning the impact of context on the performance of children with Attention Deficit Hyperactivity Disorder (ADHD) have arisen. ADHD is a neurodevelopmental disorder that significantly impairs functioning across domains. It is characterised by the core symptoms of hyperactivity, inattention and impulsivity, and a wide range of additional cognitive and social difficulties that are outlined in Chapter 2. Theoretically, the cognitive deficits which characterise this disorder have significant implications for the performance and behaviour of these children across all settings. However, there is anecdotal evidence that raises questions about the pervasiveness of cognitive deficits associated with this disorder.

Ultimately the material discussed in this chapter aims to shed light on the contextual sensitivity of children in test and 'real world' situations. It is argued that this may help to explain emerging anecdotal evidence that points to successful performance of children with ADHD on tasks that, according to diagnostic criteria, they should theoretically fail. This evidence is outlined in Chapter 2, which raises the question of how a constitutional disorder with core deficits can be subject to contextual effects. However, before examining this evidence in detail in relation to ADHD, literature relating to context and cognition in typical development and arguments surrounding the issues of making 'human sense' will be discussed in Section 1.2.

1.2 The Inter-Relationship between Context and Cognition in Typical Development: Historical perspectives

1.2.1 Piaget's Theory of Cognitive Development.

The works of Piaget were well received by developmental psychologists during the early 1950s and 1960's and remain influential to this day. His hypothesis was that biologically based intellectual structures develop in a similar way to the unfolding of embryological structures (Piaget, 1952). Intellectual structures need to be nurtured, and four cognitive mechanisms (maturation, experience, social transmission, and equilibration) allow environmental interactions to drive the development of these internal structures. The philosophical and theoretical approaches Piaget proposed gave rise to a widespread tendency to accredit cognition purely to internal mechanisms and the maturational state of the individual. His approach was of domain general knowledge acquisition, whereby knowledge acquired is adapted and changed to suit the requirements of the individual's environment. A single general learning mechanism was hypothesised to apply to all domains. This mechanism is dependent upon structural changes. The structural changes therefore allow synchronised changes in cognition, processing and knowledge across a wide range of domains. Case (1992, p 52) referred to these mechanisms as 'logical structures', defined as 'a set of internal operations that were domain independent, and whose gradual evolution and transformation were responsible for propelling children through the observed sequence of cognitive-developmental changes'. Piaget's theory predicts that all individuals will progress through the same sequence of development regardless of the particular nature of the experiences and education they encounter, and in addition assumes that once the individual reaches a given stage of development, he or she is at that level in all domains of knowledge. Essentially this approach attributes cognitive development, and thus performance, to internal features, whereas external features, such as environment or context, are somewhat backgrounded. This premise has been subject to intense scrutiny, particularly in its portrayal of cognition as content-independent, where

competencies in one area of thought are necessarily paralleled by competencies in another.

1.2.2 The importance of ‘making sense’.

A move away from a Piagetian approach to understanding cognition was prompted by several critiques of his work on pre-operational and content-independent thought influenced by perception and perceptual reasoning. Research emerged that demonstrated that children could show competencies on some tasks but not others that made similar cognitive demands (e.g Carey, 1985). Several theorists demonstrated that with small alterations to the contextual features of Piagetian tasks, young children were able to display abilities that Piaget found lacking. McGarrigle and Donaldson’s (1975) work has been highly influential in this area. They argued that the problem with Piaget’s tasks was that the way in which they were framed left their meaning ambiguous and confusing for young children. The children had to deduce what the experimenter meant by the questions they were asked, the ‘point’ of the test was not clear and therefore the questions were open to misinterpretation. It was therefore proposed that the tasks ought to be made more meaningful and salient to children as contextual cues implicitly guide behaviour.

McGarrigle and Donaldson therefore designed experiments such as the ‘naughty teddy’ test of conservation. These tasks were designed to be more salient and contextually relevant, and to avoid misleading suggestions they felt existed in the original Piagetian tasks. As predicted, when children watched ‘naughty teddy’ changing the arrangement of materials they were more frequently able to correctly ascertain that the quantity of material had not changed even though its formation had.

Chandler and Hala (1994), when studying theory of mind understanding in young children, also stressed the importance of making the task relevant to the child. The salience and relevance of the task setting certainly seems to be more pronounced when contextual information is changed so that tasks are made into ‘games’. For example,

Light, Gorsuch and Newman (1987) presented a conservation task using a standard and a game format. In the game format children were asked to move peas from a pile into a bowl using straws, the one who finished the task first would be the winner. In this context children showed a significant improvement in their ability to answer conservation questions successfully.

It was argued that the failing of 3 to 4 year old children on classic conservation and other tasks was therefore unlikely to be due to limited cognitive ability and was more likely to reflect misunderstanding by the children of the aim of the tasks and the intention of the experimenter (Light & Perret-Clermont, 1989). In short, performance seems to be highly dependent upon the way in which a task is framed. Successful performance is less likely to occur if the task simply does not 'make sense'.

The influence of language on cognition is also very important in helping the child to make sense of their world. The development of language, like perception, is embedded within the individual's environment. Sticht (1997) argues that language is the cornerstone of society which introduces the child to shared cultural values and knowledge. Reder (1992) also stressed the influence of language on the development of social norms, cultural beliefs and values. Language guides thought and self-regulation, an important aspect of cognition.

Tasks reliant on verbal and reading abilities are frequently criticised for the problems they can present to young children or those with poor verbal or reading ability. When tested with tasks which do not require good verbal or reading skills, or that do not require the child to 'second' guess what the experimenter means when he or she asks a question, children have often demonstrated cognitive skills which were previously unobserved (Bartsch & Wellman, 1985; Jenkins & Astington, 1996).

The differences between adult use of language and children's are thought to play an important part in the success of children on measures of cognition. Like Donaldson

(1978), Siegel (1991) suggested that failure on such tasks may more accurately represent difficulties in ascertaining what the question being asked actually means. Similarly, those tasks which rely too heavily on the child being able to remember a sequence of instructions can hinder the performance of young children (Lewis, 1994). Perner, Leekam and Wimmer (1984) also attributed performance to the role of the conversation between the child and experimenter. However these researchers put greater emphasis on the assumptions implicit in the conversation. If questioning prior to testing reveals a shared understanding of the nature of the object of questioning then children are likely to assume that this knowledge has already been ascertained and in post-test questioning are likely to be confused by a repetition of the same questions. Perner, Leekam and Wimmer (1984) therefore suggested that some of this confusion can be overcome with the use of a second experimenter for the post-test stage of questioning. This claim was supported by the findings of Light, Gorsuch and Newman (1987).

In summary, the argument is that cognition and behaviour are highly influenced by social and contextual features and, in particular, the way in which a task is framed. The way in which a task is framed can help children to reason through stages of the task or remember sequences of events. It may help to avoid the need to reason counterfactually (Lewis, 1994; Fritz, 1991). When allowed to participate in a naturalistic setting, young children are able to exhibit abilities previously only attributed to much older children (Bartsch and Wellman, 1995). Experience and comfort associated with naturalistic settings appear to help children to demonstrate cognition of a higher level. In contrast, settings or tasks that conflict with social rules, that are unfamiliar or unusual, that result in distraction by task irrelevant feelings such as stress and anxiety are unlikely to yield optimum performance (Bennett, 1993).

In summary, these criticisms of the Piagetian approach led to a search for theories which took account of the potential impacts of context. One such account which has received increasing acclaim in recent years is that of Vygotsky (1962).

1.2.3 Interpersonal Interaction and Vygotsky's Theory of Cognitive Development

The works of theorists such as Vygotsky slowly led to interest in some of the dimensions of cognition that appear to be influenced or moderated by interpersonal interactions and social context. In particular Vygotsky (1962) was concerned with the process by which external processes become internalised. One of the prime examples of this was the development of language and the inner voice. Vygotsky claimed that in early development language is external, existing in the environment in which the child develops. Throughout early development interpersonal interactions, shaped by the individual's culture and environment, guide the acquisition of language so that it becomes intrapersonal, and the external becomes internal. Vygotsky hypothesised that the evolution of language was the key to the expansion of uniquely human mental processes. The internalisation of language brings about the inner voice that guides both thought and behaviour, facilitating a myriad of cognitive abilities dependent upon self-regulation and reflection.

This approach led to greater consideration of the influences of social and environmental factors on cognition, with increasing interest on contextual features that enable a child to move across 'zones of proximal development', to acquire progressively more complex skills at each level of development. In particular this placed far more emphasis on the role of significant others, such as parents and teachers, on the cognitive development of the child, and the influence and encouragement of these significant others were seen to shape progression towards the next 'stage'. However, despite this recognition, focus also remained upon the processes and developments occurring within the child.

According to the Vygotskian approach to understanding cognitive development, as children grow their experiences of the external world become internalised. Together with certain maturational changes, such as the development of the brain and nervous system, this process of learning shapes both our abilities and our behaviours.

It is generally acknowledged that the development of internal representations plays a crucial role in the internalisation of children's experience of the external world. Mental representations allow us to store information on the things we encounter, such as objects, people and events, along with information we associate with these items, such as emotions, procedures, responses, actions, other activities, other people and so on. Mental representations are often referred to as schemata. Schemata are essentially a form of representation that guide behaviour and thought according to a set of rules or knowledge base that we form through experience or through social contact.

These mental representations correspond closely to the types of domain specific modules described by Fodor (1983; 1985). Fodor proposed a domain specific theory of cognition. This account views cognition as contextually dependent and is similar to the approach of Piaget only in the emphasis placed on the constraints of mental structures. However, unlike Piaget's claims, these mechanisms are viewed as individual modules that store the information required for very specific purposes. These modules are genetically specified and independently functioning, each with their own dedicated mechanisms that respond to specific types of inputs. These therefore store domain specific information. In contrast, central processing is responsible for more domain general cognitions, accessing and organising the specific modules as and when they might be needed.

This type of domain specific cognition has many supporters and it has been successful in explaining several important human characteristics that appear to be driven by unique and highly complex processes, notably language acquisition (Chomsky, 1975, 1980). In addition, the approach has been embraced by researchers interested in the origins and

neurology of developmental disorders, particularly autism. Researchers such as Baron-Cohen (1995, 1998) have led the way in providing accounts that attribute impaired functioning to deficits in specific types of processing. Leslie (1991), for example, proposed that a deficit in a specific 'theory of mind module' could account for poor social interaction despite a relatively high level of general cognitive functioning.

Mental representations, or domain specific modules, based on experience, are therefore thought to guide a myriad of cognitive processes, particularly learning and behaviour. It might be argued that without mental representation there is no cognition, just instinct and need driven behaviour. As soon as we perceive something we begin to form a mental representation of it in order to make sense of it. This would mean that learning, thought, reasoning, problem solving, are all dependent upon mental representation. If the development of these mental representations is based on experience then all cognitions are going to be influenced by our experience of context. Bryant (1974), for example, argued that for perceptually based reasoning children rely on deductive inferences, which depend on experience. Cheng and Holyoak (1985) argued that reasoning is most often pragmatic, and rather than based on formal, content independent rules of inference, is guided by context-sensitive rules and schemata. Cheng and Holyoak described these schemata as certain rules that have become internalised following specific experience, particularly social interaction. Girotto and Light (1992) described how these rules initially only apply to very specific circumstances but eventually their basic principles can be applied to offer guidance for a wide range of situations. Cosmides (1989) described these forms of mental representation as the result of species specific mechanisms that organise and frame experiences.

When activated by appropriate problem content, these innately specific frame builders... call up specialised procedural knowledge that will lead to domain-appropriate inferences, judgements and choices.

(Cosmides, 1989, p.195).

The concept of mental representations, and their role in cognition has been a central feature of Karmiloff-Smith's (1992) approach to understanding cognitive development. This dynamic approach has embraced the two distinct epistemological positions of domain general and domain specific theories. It acknowledges the strengths of both approaches and amalgamates the two to overcome weaknesses of both. Karmiloff-Smith rejects the notion that development follows domain general changes in representational mechanisms, and that modules are pre-specified for the information they contain. Instead, she describes how the acquisition of knowledge is directed by innate principles that guide the development of broad and flexible mental representations that influence learning and behaviour. Karmiloff-Smith describes how children are biologically predisposed to attend to certain characteristics of items in their environment. These encounters then inform the development of quite specific mental representations. Initially these domain specific representations will constrain learning and behaviour, but eventually, as time passes, they may become more flexible through the process of 'representational redescription', a domain general mechanism that slowly transforms implicit procedural knowledge into explicit representations by way of four levels of change (Karmiloff-Smith, 1994).

1.2.4 Social Constructivism and Contextualism

More recently, there is an emerging school of thought that places a much greater emphasis on context, arguing that cognition is almost never decontextualised. The sociocultural view of cognitive ability, sometimes referred to as social constructivism or contextualism, looks at cognition in society and culture and its relationship with the cognitive development of the individual. For example, the guidance and teaching of others directs the way a child comes to understand their world and communicate their experiences. The guidance that is given will depend on the attitudes and approaches adopted by the social or cultural group.

In short, this perspective largely sees cognition as being ‘situated’; cognition is dependent upon the interactions between the individual and the particular task faced (Snow, 1994). There are many possible combinations of situational factors that can impact on cognition and performance. For example, task demands can interact with environmental characteristics, and person variables such as ability, temperament and affective state. Snow (1994) believed that these factors will interact with ‘affordances’ that will also have an impact on performance. The concept of affordances was taken from Gibson’s (1979) theory of perception and refers to both the demands and the opportunities that the individual perceives the task offers. To summarise, Snow (1994) believed that person and situational variables and the interactions between them only impact on cognition and performance depending on the way in which the situation and the demands are perceived. Snow conceptualised person and situational variables as ‘task, treatment and context characteristics’ which include features such as: ability and personality; the individual’s evaluation of elements of ambiguity, risk, and stress; the level of importance placed on the outcome and how novel, meaningful, relevant and complex the task is to the individual; also of importance is the individual’s style and structure of teaching and learning, and their dominant symbol system; in addition to the task type, particularly in terms of the desired aim or goals of the task and the recommended strategy for reaching this desired goal (Snow, 1994).

Butterworth (1992) also described how this emerging approach to understanding cognition proposes that thought is necessarily contextually bound due to the influence of perception and language, the development of both being strongly influenced by interpersonal experiences unique to the individual. Butterworth argued that perception is necessarily context bound as it places the individual in their environment and derives meaning from experience. Therefore the role of perception in thinking means that cognition is naturally ‘situated in the world’ (Butterworth, 1992, p 30).

The notion arises that learning is never decontextualised as children will always refer to representational knowledge of similar experiences, even if only tenuously related, to make sense of the task ahead of them (Mercer, 1992). Light (1986) described this form of intellectual development as 'recontextualization (rather) than decontextualization' (Mercer, 1992, p 32). This can explain findings, such as those of Donaldson and colleagues, which illustrate successful cognition in the presence of additional contextual information. The familiar contextual information appeared to assist children to deduce what was being asked and to demonstrate cognitive competence. Where a task makes natural sense to children due to contextual information they do not need to try to guess why they are being asked to do the task, the goal of the task is clear to them and they can use experience as a guide.

According to Sticht (1997) experience is essential for cognition but individual experiences will only make sense to the individual through the teaching of others; society and culture provide the context. The argument is presented that the individual will learn the value placed upon particular skills from their social group.

This is a view reminiscent of Mead's (1934) 'symbolic interactionism' theory of development. Mead described how individual experience of items or events does not necessarily result in an understanding of these phenomena. Instead, Mead believed that children come to ascribe meaning to objects, actions and events through shared social activity and social signs. The actions of others guide the child's understanding of the significance of those items or actions.

Similarly, Mercer (1992) stresses how the 'cultural settings in which learning tasks are attempted are not easily separated from the tasks themselves'. Mercer discusses a range of issues that contribute to this situation, one of the most influential being the concept of appropriation. Like Piaget's 'assimilation', appropriation is described as the process whereby everyday observation of activity around them leads children to attribute different

information, qualities or rules to objects and events that are the same, or similar to those already experienced. Mercer refers to the work of Newman, Griffin and Cole (1989), who describe how 'the objects in a child's world have a social history and functions that are not discovered through the child's unaided explorations' (Newman, Griffin and Cole, 1989, p 62). Appropriation therefore implies cultural and contextual definition and can offer an explanation for how young children appear spontaneously to attribute properties and concepts to items, activities and events they have not experienced directly.

Research into these social influences on cognition has resulted in investigation of concepts widely referred to as 'socio-cognitive conflict' and 'social marking'. Sometimes social interactions can lead an individual to encounter individuals whose cognitions conflict with his or her own. Researchers such as Doise and Mugny (1981), Littleton and Light (1999), Perret-Clermont (1996), Perret-Clermont and Nicolet (2002), and Schwarz *et al.* (2000) have concluded that the resolution of this conflict in social settings can be an important catalyst for developing thought and promoting reasoning or learning strategies, allowing children to reach conclusions they would not be able to reach alone. Once they have experienced these conflicts, findings have indicated that children are able to adopt these new strategies when working in isolation. Social marking refers to the process by which cognition, frequently in novel, or problem solving situations, is guided by social rules.

According to this theory the presence of another person during task performance will present the individual with an alternative perspective to their own, and therefore another guide for performance. Doise, Mugny and Perret-Clermont (1981) reviewed several socio-cultural impacts on performance, in particular the impact of working in pairs or in groups compared to working independently. Under certain circumstances children working in pairs or groups have showed more success at task performance and greater development in cognition than children who work alone. As outlined above, this has

widely been attributed to the consideration of alternative and conflicting perspectives on the possible solutions to the task presented by another person. Relationship context (i.e. the nature of the relationship between participants) and shared understanding of social rules associated with these relationships (Labov, 1972; Rommetviet, 1992) appear to drive individuals to arrive at a shared view of the task they are faced with and ultimately a shared view of the solution (Perret-Clermont, Carugati, and Oates, 2003). In short, researchers such as Doise (1986) and Rijsman (2001) have illustrated how it is not just the physical or logical characteristics of a task that guide cognition. Social rules associated with the context in which the task is presented have also been seen to influence performance. If the rules being applied to a task match or fit the social rules ascribed to the context then children have been seen to successfully perform cognitive tasks. However, if the rules for the task conflict with the socially appropriate rules for conduct then performance has been poor. In other words, if the task makes sense to a child socially then he or she is able to perform it at a much higher level.

Some researchers have argued that this phenomenon is particularly relevant when children interact with adults. Schubauer-Leoni (1986) and Grossen (1988) believe that adults both talk and behave in ways that help children to demonstrate their capabilities. However, in contrast to the observed impact of adults on children's problem solving, the way in which psychologists and experimenters interact with their participants has been seen to negatively affect their performance. Perret-Clermont, Schubauer-Leoni and Trognon (1992) believe that researchers are actively seeking particular responses, and that this results in under valuation of responses that do not fit these criteria, such that children are seen to 'fail' the task even when they are otherwise competent.

Associated with this effect is the issue of participant interpretation of the task. Berg and Calderone (1994) argue that variability in person-situational interaction and thus problem solving performance, both in laboratory and everyday settings, can often be explained by

differences in the way individuals assess and interpret the problem facing them. For example, these researchers found differences in interpretations with changes in age and gender. They conclude by stressing the need for greater consideration of the fact that even with the most careful planning, the experimenter's desired interpretation of a task may not result in the same interpretation by the participant and therefore might also result in the implementation of quite different problem solving mechanisms to those the experimenter desired to investigate. This must certainly be considered when examining the contextual sensitivity of the performance of children.

The field of psychology, as exemplified by Piaget, has therefore been criticised by theorists and researchers working from perspectives such as the social constructivist school of thought. Ceci and Roazzi (1994) stress the importance commonly attributed to psychological processes and the relative lack of emphasis placed on context. These researchers discuss the way in which context has been seen as 'superfluous' to developmental theories, and although context has been acknowledged, it has often been seen as somewhat 'trivial' and as a factor that needs to be controlled. They believe that until very recently 'context is viewed as an adjunct to cognition, rather than as a constituent of it' (Ceci & Roazzi, 1994, p.75). Ceci and Roazzi (1994) believe that there are at least three types of context that contribute to cognition: the social context, the mental context, and the physical context. Certainly the types of contextual influences discussed in this section can be categorised in terms of these three types of context.

The importance of each of these different contexts on cognition has often been highlighted by research that has documented changes in performance following alteration to simple task characteristics that change the contextual dimensions of the task without changing the cognitive processes and demands of the task (Ceci & Bronfenbrenner, 1985). Ceci and Bronfenbrenner (1985) and Ceci (1990) have demonstrated the potential impacts on cognition of changes to both physical and social contexts using a research

methodology referred to as a 'dual context paradigm'. This paradigm involves a repeated measures design whereby participants are asked to complete the same task in at least two different contexts. The hypothesis presented by Ceci and Bronfenbrenner (1985) and Ceci (1990) was that cognition can become more effective across settings depending on the strategies or knowledge structures that the particular context activates. One particular dual context paradigm used by Ceci and Roazzi (1994) involved a video game versus a traditional test context comparison. The argument presented by Ceci and Roazzi was that the child's perception of a task is critical in influencing the strategies or knowledge structures that are activated.

For instance, if a task is perceived as a video game it may help recruit a set of strategies that children have acquired to conquer video games that might not be recruited if the same task is perceived as a type of test.

(Ceci & Roazzi, 1994, p.77).

Indeed the computer game playing setting and its potential influences on cognition and performance is one that has been receiving an increasing amount of interest in recent years.

1.2.5 The potential impact of computers on cognition: interaction between the individual and the computer game playing setting.

Ceci and Bronfenbrenner (1985) also presented 10 year old children with a dual context paradigm using two computerised tasks. Essentially this experiment replicated the task demands used by Ceci and Roazzi (1994). The children had to predict where upon the computer screen a test item would move to. Each test item's migration across the screen was determined by its size, colour and shape, but the rules associated with each of these were not given to the children. Thus, in order to successfully predict the test item's movement the children needed to learn the rules associated with size, colour and shape and to combine them according to the specific test item's features. For one of the

computerised tasks the test items were different geometric shapes and the children were asked to point to the place on the screen where they thought the shape would move to. This task was presented to the children as a standard laboratory based reasoning task. After 750 trials the children were performing slightly above chance, and were reported to have learnt a few specific combinations of features but not all of the underlying rules.

In contrast, for the other computerised task the test items were different flying creatures (bird, bee, butterfly) and sound effects were added. The children were asked to move a butterfly net cursor, across the screen, to the place where they thought the creature would move to. Thus, this computerised task resembled a computer game and the children had a salient reason for predicting movement, i.e. to capture the creature. Importantly, the underlying rules for direction of movement were the same as for the geometric shapes computerised task. After 300 trials the children were performing almost at ceiling level. Performance therefore differed dramatically across the two contexts despite requiring the same reasoning skills. Ceci and Bronfenbrenner concluded that children could solve algorithms in a video game playing context with much greater success than they could in the 'disembedded' laboratory context.

To date there appears to be relatively little research that addresses the impact of computer game playing on the cognitive performance of children. There is however a body of research that provides a glimpse of the types of impact computers might have in the context of collaborative learning. The increase in the use of computers in the home and in education has sparked a great deal of curiosity in the impact of computer mediated task presentation. There has certainly been interest in the use of computers in education. Littleton and Light (1999) make an important observation when they discuss how resource allocation and issues of access to computers in schools have often resulted in children using computers in groups or in pairs. As research into the impact of social effects on cognition and performance in other presentation formats suggests, there are

certain gains to be achieved when computers are used in group settings or for collaborative learning. This social context can allow the sharing of ideas and individual skills and resources and conflict can be beneficial for finding shared solutions and understandings, thereby increasing success. Working in groups certainly appears to have positive impacts on performance, however, it is important to note that these effects are likely to differ according to group composition and gender, in addition to differences in computerised task demands and characteristics (Littleton and Light, 1999). For example, Underwood and Underwood (1999) found that on more problem-orientated tasks, children's performance improved when they worked collaboratively and through the sharing of ideas. In contrast, the sharing of ideas was not seen to be as important for success to be achieved on a less problem-orientated task. In this setting the group's success on computer tasks depended on their ability to agree on task behaviour.

Underwood *et al.* (1990) also discuss how gender seems to be one of the most constant determinants of performance on computer-based interactions, possibly due to perceptions of male expertise and lower levels of female confidence, and this observation is certainly stressed by the research outlined by Littleton and Light (1999), and by Light *et al.* (2000) and Keogh *et al.* (2000).

Exploration of the role of the computer in these interactions has generally concluded that the type of structure and feedback offered in this context might be of significance. Howe and Tolmie (1999) also observed significant and positive impacts of collaborative learning with computers and concluded that the use of the computer had an important role to play in 'facilitating productive aspects by structuring discussion and providing feedback on joint solutions'. These researchers hypothesised that an important facilitating feature of computers is that they are able to support two processes that are critical for group learning: these are verbal interaction and action conducted in shared space. Thus, computers are important as they can provide an environment for action based learning while also giving unambiguous feedback. At the same time, other members of the group

can observe the actions and feedback given to others and can also learn from it. In effect, Howe and Tolmie suggest that the computer helps to structure the context in which children are performing, by creating the 'structure of work practices' shaping action and presenting feedback and information about what is required. Thus, the understanding of task meaning, something that has been argued to be of great significance in terms of the impact of context on cognition (section 1.2.2), can be aided by computers through the way in which they can structure and frame a task.

Similarly, Mercer and Wegeriff (1999) also argued that computers can play an important role in shaping the performance of children in collaborative learning settings. These researchers refer to the importance of the types of dialogue that take place during these interactions. In particular, they describe how the computer can help frame the dialogue that takes place and can guide it towards desired outcomes. Mercer and Wegeriff outline the following stages of computer-participant interaction as being useful in this respect: initiation (by the computer), discussion (between children), response (by children acting together) and follow up (by the computer). Once again, these researchers stress the importance of the feedback given by computers in shaping the discussion that takes place within the group.

In addition to this aspect of computer mediated task presentation, Säljö (1999) describes how computers offer the opportunity for greater visualisation, or representation, of all sorts of complicated types of conceptual knowledge or phenomena. This also allows knowledge to be manipulated in ways that might otherwise be impossible. This can provide greater opportunity for trial and error, in 'safe' environments. In short, Säljö (1999) argues that computers can help make the abstract more tangible.

To summarise, the information presented in this section places a great deal of importance on contexts that are salient, familiar or make sense to the individual being tested or studied. Computer based contexts, and particularly computer game playing settings,

appear to have been successful in facilitating certain improvements in performance in a range of different ways. As Littleton (1999) stresses, the expectations of the computer user must not be underestimated as these can be ‘powerful mediators’ of activity. This aspect of interaction with computers is certainly one that is likely to impact on the performance of children on computerised tasks and games. The information presented here suggests that careful consideration be made of the potential impact of computers on performance. The expectations of the game player are of particular importance as they are likely to be closely intertwined with their motivation to complete a task or play a game. This is also discussed throughout this thesis and in greater detail in Chapters 2, 9 and 10.

1.3. Context Specificity of Children’s Problem Solving and Reasoning

From the preceeding sections it has become evident that one of the central cognitive processes, the ability to problem solve or reason, is likely to be strongly influenced by the degree to which the context makes sense to the individual, the thoughts or knowledge the setting evokes and the degree to which the individual is motivated by it. Sternberg (1984) also hypothesised that the role of task novelty and automatisisation of the response required are important contextual features that will affect performance. Sternberg argued that if a task is too novel then the individual has no experience to guide their performance.

Correspondingly an old task presented in a new environment can be much more difficult to perform than the same task in a familiar environment and complex tasks appear to be performed much more easily if the processes required have already been automatised (Sternberg, 1984). Sternberg argued that there is a novelty/automatisation trade off, where the more automatised the response the more resources become free to process aspects of task novelty.

Sternberg (1984) defined ‘intelligence in context’ as purposeful adaption of the real world environment relevant to one’s own abilities. This, combined with the information presented in the preceeding sections, would appear to suggest that situations that promote

optimal performance would be those that are more ecologically valid to the individual being tested. Several researchers have investigated this hypothesis.

The importance of examining problem solving performance in familiar contexts was emphasised by the findings of Gay and Cole (1976). These researchers found that the performance of American school children far exceed that of African (Kpelle) child traders, who had not experienced formal schooling, on several typical academic tasks. However, the performance of the African traders exceeded that of the American children in tasks that required children to make estimates of amounts of rice. Similarly, Carraher, Carraher and Schliemann (1991) found that although Brazilian child street vendors performed poorly on school arithmetic tasks, they were able to correctly solve all of the problems they encountered if presented as transactions experienced in their workplace. These researchers concluded that context-embedded problems were much more successfully solved than those without context. Although these researchers suggest that this might at first be seen as support for Piaget's claims that young children are only capable of thinking in more 'concrete' terms, they go on to stress how the tasks used required mental computation without the guide of prompts or aids. They argued that this type of mental manipulation requires abstract thought and is not frequently seen in those whom Piaget decribed as 'concrete' thinkers. This thereby provides yet further support for the need to examine cognition in context.

Schliemann and Nunes (1990) found that fishermen, who had either little or no formal education, were able to solve complex proportional reasoning tasks when conceptualised in terms of the prices of fish. Further, Schliemann and Magalhaes (1990) found that although Brazilian cooks did not demonstrate proportional reasoning skills on tasks that required them to solve problems in a cookery context and in the context of mixing pharmaceutical ingredients, they were successful on tasks involving the same arithmetical problem when those tasks were framed within the context of a sales transaction.

Schliemann and Carraher (1992) describe this sales transaction as a context that socially defines the use of proportional reasoning (Schliemann and Carraher, 1992, p 61).

It is argued that reasoning and problem solving invoke the use of task relevant schemata, organised mental models containing information about rules and step by step processes that guide behaviour. These schemata are largely influenced by cultural norms and procedures (D'Andrade, 1981). Performance on problem solving or reasoning tasks is therefore influenced by the extent to which the problem or task relates to the individual's schemata. The introduction of social context therefore introduces the concept of 'social marking'. Light and Perret-Clermont (1989) describe how the extent to which a task can be mapped onto social norms or rules will impact on the ease with which the task is performed. For example, if the child can understand the task in terms of the competitive rules or elements of a game then they will complete it more easily. Social marking does not require the presence of others but is affected by the social experience of other individuals. This provides a framework in which the test setting is understood.

The examples described above typify the extensive discussion that has surrounded the influence of context on cognition, particularly learning, problem solving and reasoning. Researchers have debated the view that learning is always situated due to the way in which tasks and activities are never independent from the way they are contextualised by both teachers and learners. This has implications for the way in which competence and learning are assessed. Some of these implications are summarised in the following section.

1.4 Performance in Context: Implications for the Study of Cognition

1.4.1 Analysis of Competence

Many theorists and researchers have proposed that contextual influences deserve greater consideration during examination of the potential influences on performance. For example, Mercer (1992) argued that context and culture should be included in any

analysis of competence, with emphasis on the settings in which competence is demonstrated. Rather than isolating these variables within the experimental approach, Mercer offers the approach of Newman, Griffin and Cole (1989) for consideration. These researchers are noted to have suggested that rather than focusing on performance in terms of success or failure, one should observe and note the quantity and quality of the assistance required for success as an indication of cognitive competence. The emphasis would therefore turn to understanding the process of learning rather than performance outcomes.

Similarly Snow (1994) argued that competence, otherwise referred to as ability or intelligence, is necessarily situated, depending upon the interactions between person and situational variables. In essence, Snow believes that it is the ability of persons to adapt to suit task demands, to 'tune' themselves to situational variables, or for situations to suit persons that determines competence. Ability cannot therefore be attributed to either person or situation alone, but is the 'interface' between person and situation. To summarise this view of competence and intelligence Snow stated:

abilities are affordances, properties of the union of person and environment that exhibit the opportunity structure of a situation and the effectivity structure of the person in taking advantage of the opportunities afforded for learning. Particular persons are tuned or prepared to perceive particular affordances in a situation that invite the particular actions they are able to assemble. But inabilities are also artefacts, properties of the interface between an inner personal environment and an outer situational environment

(Snow, 1994, p.31).

The issue of the assessment of competence as opposed to performance is therefore one that is centered around the issues of cognitive and ecological validity. Berry (1984) believed that experimental psychology cannot say anything conclusive about cognitive competence, the role of causal relationships, experience, learning, behaviour or responses

when the experimental setting consists only of examination of scores within a specific, typically laboratory based, test context. This line of thought led theorists such as Campbell (1957) to conclude that experimental psychology lacks external validity. Instead it is argued that performance must be examined in more ecologically valid settings in order to give a more representative view of cognitive development and competence. According to Berry the local context sets the stage for performance and 'no understanding of cognitive abilities is possible until the nature of their setting is also understood' (Berry, 1984, p 66). This line of thought proposes that the use of formal testing in controlled settings, particularly with the use of standardised instruments, indicates only where performance is different. Berry and Irvine (1984) argue that this approach therefore illustrates deficiency and not competence.

1.4.2 Berry's (1984) Framework: Four types of Context and their Impact on Cognitive Performance

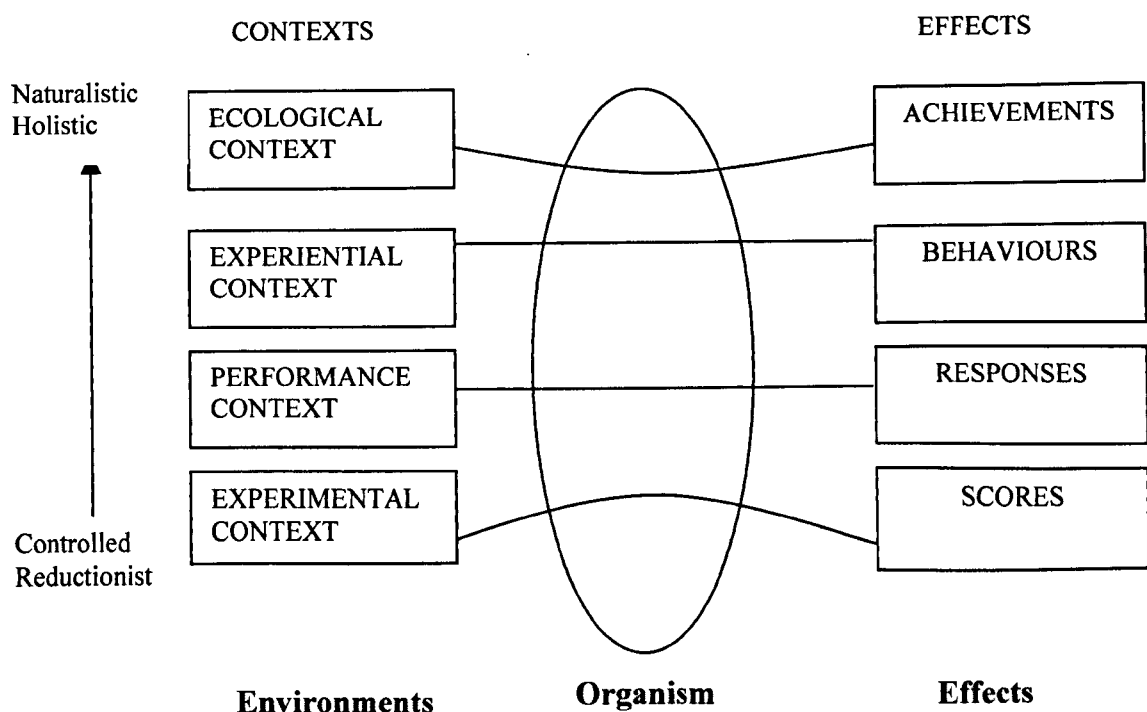
In support of this approach Berry developed a framework for understanding the role of context. This framework considers the impact of four main types of context on cognition and performance. At the highest level there are the naturalistic and holistic contexts. These include the ecological context and, to a lesser extent, the experiential context. The ecological context is described as the 'natural-cultural' habitat, the relatively permanent contextual features for human action that include the physical 'life space' and mental 'psychological world'. The ecological context impacts on complex long standing developed behaviours that act as adaptations to the environment. The experiential context refers to the experiences gained throughout life that form the basis for learning. These impact on behaviour, attitude and response styles learned over time.

At lower levels there are the performance and experimental contexts that are more controlled and reductionistic. The performance context refers to a specific and limited set of immediate environmental circumstances that account for very specific behaviours and

immediate responses to given stimuli. The performance context is therefore of particular interest for this thesis which aims to examine the influence of context on the immediate behavioural responses of participants.

The experimental context is also of particular interest in this thesis. The experimental context is determined by the environmental or task characteristics designed by the psychologist to elicit a particular response. Berry argued that this context also directly impacts on performance in terms of the behaviours that are recorded, measured or observed during testing. According to this model, demonstration of sensitivity to contextual changes should be followed by close scrutiny of the environmental and task characteristics integral to the experimental design.

Berry also argued that if the experiment has ecological validity then the performance of the individual during testing has behavioural validity. According to this assumption it can be predicted that if participants perform differently across experimental contexts, it will be the most ecologically valid of these contexts that has the greatest potential for providing a more representative demonstration of their competence. Berry's framework is summarised in Figure 1.



In summary, successful performance of tasks in experimental settings, particularly for children, appears to be dependent upon the children's ability to access 'subtle, culturally elaborated abstractions' in order for them to make better sense of the situation (Light and Perret-Clermont, 1989, p. 109).

In light of these views on cognition in context the desire to distinguish clearly competence from performance may not be feasible. As Butterworth (1992) comments 'perhaps competence is a function of contextual variables and this is why performance varies from context to context'. Indeed, Goodnow and Warton (1992) present the argument that context and cognition are interrelated in a pluralist fashion, and that study of these phenomenon can be subdivided into analyses of context and analyses of cognition.

The preceeding sections in this chapter have discussed some of the issues concerning the inter-relationship between context and cognition in typical development in order to inform understanding of the possible mechanisms influencing the performance of children across settings. In summary, this literature suggests that behaviour and performance can never be decontextualised. However, these sections have been rather nomothetic in their approach to the arguments surrounding the issues of making 'human sense' and the context specificity of children's problem solving and reasoning. Questions remain concerning the generalisability of these findings to individuals working alone and to individuals with a range of different abilities and interests.

1.5 Individual Differences

As outlined in Sections 1.1 to 1.4 of this chapter, empirical research has demonstrated that context can influence performance. But there are other factors which influence performance and it is important to consider if these might interact with, or even overrule, any effects that context might have. Possible contenders include intelligence, personality, temperament, cognitive affect, and motivation. In short, factors which are different between individuals. As Gardner (1983) pointed out, it is important to remember that individuals' cognitive styles will differ, reflecting various strengths and weaknesses. This section therefore takes a brief look at the influence of some of these factors on performance before considering whether there is any evidence that these interact with contextual effects. The final section of this chapter, Section 1.6, concludes by considering how the interaction between some of these individual differences and contextual effects might be studied.

There is a large body of research that demonstrates the impact of individual differences in personal preference and ability on cognitive development and performance. Sternberg, for example, (1988) hypothesised that there are important individual differences in thinking style that need to be considered when looking at the interaction between individual differences and context effects. And Revelle (1991) described how individual differences in affective attitudes are also likely to impact on what attracts, motivates, or engages the individual, and the interaction between context and performance. Crozier and Hostettler (2003) demonstrated that performance on vocabulary and mental arithmetic tests conducted in face to face settings was significantly affected by children's shyness; Anderson (1990) concluded that the effects of stimulant drugs, sleep deprivation, time of day, and impulsivity on behaviour was mediated by level of arousal; and Matthews (1989) and Matthews *et al.* (1989) observed that performance can be affected by mood. Variation in the intensity of energy expended, interest and motivation (Humphreys & Revelle, 1984), direction of affective state (Watson & Tellegen, 1985) and energetic and

tense arousal (Thayer, 1989) have been shown to be important factors determining individual variations in performance.

The model proposed by Revelle (1991) combined some of these potential influences on cognitive model of individual differences and performance. Revelle (1991) described how biological predispositions, memory of past events, and personality traits combine with situational factors, including environmental cues, to produce motivational states (both positive and negative affect). These interact with situational manipulations and stressors (such as time of day, noise levels, presence of stimulants) to impact on behavioural responses such as approach or avoidance mechanisms, and cognitive performance.

Broadbent (1958, 1971) also examined the influences of personality, processing ability and motivation and concluded, in line with optimal arousal theory (Anderson, 1990; Broadhurst, 1959; Hebb, 1955; Humphreys and Revelle, 1984; Revelle, 1987, 1989; Sanders, 1983, 1986; Yerkes & Dodson, 1908) that there are important individual differences in optimal arousal and motivation that can impact on performance. In addition, Broadbent (1971) studied the impact of different situational 'stressors' on performance and concluded that individuals respond differently to different stressors across situations depending on their personality.

As illustrated above, a number of researchers have argued that both context and individual differences are likely to interact with one another to have complex effects on performance. However, are there situations where individual differences might overrule contextual effects on performance? Despite the observed effects of context on performance it must be recognised that the individuals' potential for cognitive development and therefore performance, will also depend upon innate characteristics transmitted at birth that determine cognitive capacity. Anatomical structures and functions, that make the individual capable of cognition, will be determined by genetics

and physiology in addition to environment. Physical and mental health will determine how well an individual can function (Sternberg & Grigorenko, 1997). It seems logical that such innate capabilities will impinge on the impact that context has on cognition. Indeed some researchers claim to present evidence to indicate that the effects of biologically or genetically determined individual differences can exert a greater effect than any effect due to context, and as such they should not be underestimated. For example, Depue and Collins (1999) studied the similarities in the effect of extraversion (characterised by higher degrees of interpersonal engagement and impulsivity) and the influence of positive incentives on the behaviour of different mammals. These researchers concluded that neuroanatomical sources of difference between individual animals determined the processing of incentive motivation and thus extraversion. In short, they found evidence to suggest that individual differences in neurological function determined sensitivity to incentive context and incentive motivation and therefore performance and behaviour. In other words, individual differences in neurology determined the degree to which the animals were influenced by changes in context. In addition, Bouchard and McGue (2003) also argued that genetic factors affect the impact of context. These researchers reviewed a wealth of material concerning the methodologies, theories, approaches and research findings relating to individual differences and behavioural genetic studies. They concluded that there is clear evidence that virtually all individual psychological differences, including cognitive ability, personality, social attitude, psychological interests, and psychopathology, are moderately to substantially heritable (when reliably measured) and that these will determine performance across contexts

This debate seems particularly relevant to the study of the impact on performance across contexts of individuals who have neurodevelopmental disorders. In such disorders individual differences in neural networks account for much individual variation in

executive skills including fine motor skill, physical coordination, and capacities for planning, organization, strategic thinking and expression (Baddeley et al., 1997; Leclerq et al., 2000; McDowell, Whyte & D'Esposito, 1997; Miller, 2000; Stuss et al., 1983). These executive functions are believed to be key elements of cognition, particularly as executive function is critical in determining self-regulation. Those who have developed a greater degree of self-regulation are thought to be behaviourally more flexible and adaptable (Berk, 1992; Kanfer & Karoly, 1972; Skinner, 1953) and seem to have greater control over appropriate behaviour (Barkley, 1997a; Bronowski, 1977; Fuster, 1989). Factors such as these must surely impact on the degree to which context will affect performance. Importantly, deficits of executive function are hypothesised to be at the heart of many developmental disorders (Strayhorn, 2002). It is certainly likely therefore, that, due to the nature of cognitive impairment or function implicated in such disorders, this is perhaps one of the few instances in which individual differences might be hypothesised to contribute more to performance than differences in context.

1.6 Conclusions

Context is important for cognition due to a range of complex interactions between person and situational variables. Certain contextual features can help us to 'make sense' of situations, can determine the way in which the context is perceived and can impact on motivation, affective state and energetic intensity expended on an activity. Viewed from the social constructivist perspective, context guides thought and learning, reasoning and problem solving, action and reaction and interacts in particular ways with person variables. The implication in terms of the measurement of cognition, particularly for children, is that the way in which a specific task is framed, its specific features and characteristics, will have an important impact on the way in which the task is performed. This places greater emphasis on the need for contextualisation to be appropriate for the individual. Furthermore, there is the argument that the context must not only 'make

sense' to the individual, it must also interest or motivate them in order for the context to have the most positive impact on behaviour and performance.

However, individual differences in physiology and genetic make up may also impact on an individual's temperament and their capacity to acquire certain cognitive abilities and to behave in the appropriate manner. It may be less likely that contextual differences will have an impact on the performance or behaviour of atypically developing children whose development can be attributed to a physiological or neuroanatomical condition. Attention Deficit Hyperactivity Disorder (ADHD) is viewed as a constitutional disorder associated with a range of executive impairments, core deficits, and specifically a pervasive deficit of inhibition. As such, it might be argued that core features of the disorder should not be subject to contextual effects. Chapter 2 reviews theory and research that has informed current understanding of ADHD. It concludes by outlining emerging evidence that contextual characteristics may indeed impact on the performance and behaviour of children with ADHD when playing computer games. Thereafter, the remainder of the thesis describes a set of empirical studies that set out to test whether or not this is the case.

Chapter 2

Current Understanding of ADHD

This first part of this chapter provides a description of ADHD, its history, symptoms, characteristics and diagnostic criteria, and the treatment approaches used. The aim of sections 2.1 to 2.4 is to investigate material that may shed light on the nature of the disorder, so that in the latter half of the chapter, sections 2.5 to 2.6 ,evaluation of related material, theory and research findings can take place to investigate whether individuals with ADHD are likely to be subject to context effects.

The earlier sections of the chapter therefore outline the cognitive deficits of executive function (EF) commonly associated with ADHD and the neurology associated with it. This is followed by a discussion of the evidence in support of both EF and frontal lobe deficits in ADHD. One major focus of current debate is the role of inhibitory deficits in the disorder. A wealth of empirical evidence proposes that inhibitory problems are a key characteristic of the disorder, and this research is summarised. The nature of these inhibitory deficits would suggest that the performance and behaviour of children with ADHD will be significantly impaired across all domains and contexts.

However, as outlined in Chapter 1, central to this thesis is the notion that situations may exist in which these executive and inhibitory deficits are not exhibited. The latter part of the chapter therefore considers material, theory and research findings, that present arguments both for and against the potential effect of context on the performance and behaviour of children with ADHD. Anecdotal evidence suggestive of good executive and inhibitory performance is also presented together with a discussion of the potential importance of these observations for the epistemological debate outlined in Chapter 1.

2.1 What is ADHD?

2.1.1 Symptoms and Diagnostic Criteria.

Attention Deficit Hyperactivity Disorder, ADHD, is a condition characterised by distractible, impulsive, hyperactive, inattentive, impatient and self involved behaviour, experienced to a degree inconsistent with the individual's developmental level (American Psychiatric Association, 1994; Barkley, 1996a; World Health Organisation, 1992). Most notably, individuals with ADHD exhibit poor impulse control, lack of self-regulation and poor adaptive functioning. Parents and teachers report frustration and anger as children with ADHD do not attend to and fail to follow instructions, fidget, go off into 'dream like states', are often accident prone, totally disorganised and disregard any rules for appropriate behaviour. This causes difficulties across emotional, social, academic and cognitive domains (American Psychiatric Association, 1994; Barkley, 1996a; Hallowell & Ratey, 1994; Kirby & Grimley, 1986). Children with ADHD consistently underachieve academically, with at least 50 per cent failing annual school exams by adolescence (Zentall, 1993). Barkley (1997c) reported a 90 per cent likelihood of school failure and a 50 per cent likelihood of underachievement in employment for individuals with ADHD (Barkley, 1990; Weiss & Hechtman, 1993). This highlights the persistence of the disorder into adolescence and adulthood (Meaux, 2000). More than 50 per cent of these individuals will develop conduct disorders exhibited as delinquent and anti social problems. A third of these individuals are also expected to show early substance abuse (Barkley, 1997c; Barkley *et al.*, 1990; Biederman *et al.*, 1996; Gittelman *et al.*, 1985; Satterfield *et al.*, 1982; Weiss *et al.*, 1978). Interestingly ADHD is most common in males, particularly in early childhood. Although some females also have ADHD the disorder is often diagnosed later in childhood and its expression can be somewhat different to that seen in males. Anecdotally it is often reported that females more often appear to meet the criteria for the inattentive subtype of ADHD. If this is the case, then females with ADHD would less commonly display the behavioural problems associated

with the combined or hyperactive subtypes. This combined with cultural expectations for females in terms of their temperament and achievements, may therefore mean that their ADHD is attributed to characteristics associated with their gender and is undiagnosed.

The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III, American Psychiatric Association, 1980) first used the term Attention Deficit Disorder, ADD, to refer to inattentive and hyperactive behaviours previously termed 'hyperkinetic' (APA, 1968). DSM-III listed three major features of ADD: inattention, impulsivity and hyperactivity. The disorder was also described as consisting of two subtypes; ADD/H, Attention Deficit Disorder with hyperactivity, and ADD/VO, Attention Deficit Disorder without hyperactivity. The consistency and frequency of hyperactive symptoms led to expansion of the term ADD in later versions of DSM (III-R, 1987; and IV, 1994) to ADHD. ADHD was seen as a one-dimensional disorder, and due to lack of consistent research findings reference to the subtypes described in DSM III was dropped (Barkley, 1990; Barkley & Grodzinsky, 1992; Doyle *et al.*, 2000; Morgan *et al.*, 1996; Pennington & Ozonoff, 1996). However, the wealth of variation of symptoms gave rise to debate concerning definition, criteria for diagnosis and the need to account for subtypes. DSM III-R was criticised as being put forward prematurely (Cantwell & Baker, 1988).

Following further empirical research DSM IV reverted to include subtypes similar to those included in DSM III (Morgan *et al.*, 1996). DSM IV incorporated a predominantly hyperactive subtype, a predominantly inattentive subtype and a combined subtype. To meet DSM IV ADHD criteria an individual must exhibit either six or more symptoms of inattention, or six or more symptoms of hyperactivity-impulsivity 'that have persisted for at least six months to a degree that is maladaptive and inconsistent with developmental level' (American Psychiatric Association, 1994). To meet the Predominantly Inattentive subtype criteria six of the inattention symptoms must have been exhibited. To meet the Predominantly Hyperactive subtype criteria six of the hyperactivity-impulsivity

symptoms must have been exhibited. To meet Combined Type criteria an individual must have exhibited six of the inattention symptoms in addition to six of the hyperactivity-impulsivity symptoms.

Inattentive symptoms include:

- a) often fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities
- b) often has difficulty sustaining attention in tasks or play activities
- c) often does not seem to listen when spoken to directly
- d) often does not seem to follow through on instructions and fails to finish schoolwork, chores or duties in the workplace (not due to oppositional behaviour or failure to understand instructions)
- e) often has difficulty organising tasks and activities
- f) often avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)
- g) often loses things necessary to tasks or activities (e.g. toys, school assignments, pencils, books, or tools)
- h) often distracted by extraneous stimuli
- i) often forgetful in daily activities.

Hyperactive symptoms include:

- a) often fidgets with hands or feet, or squirms in seat
- b) often leaves seat in classroom or other situation where it is inappropriate (in adolescents or adults this may be limited to subjective feelings of restlessness)
- c) often has difficulty playing or engaging in leisure activities quietly
- d) often 'on the go' or often acts as if 'driven by a motor'
- e) often talks excessively.

Impulsive symptoms include:

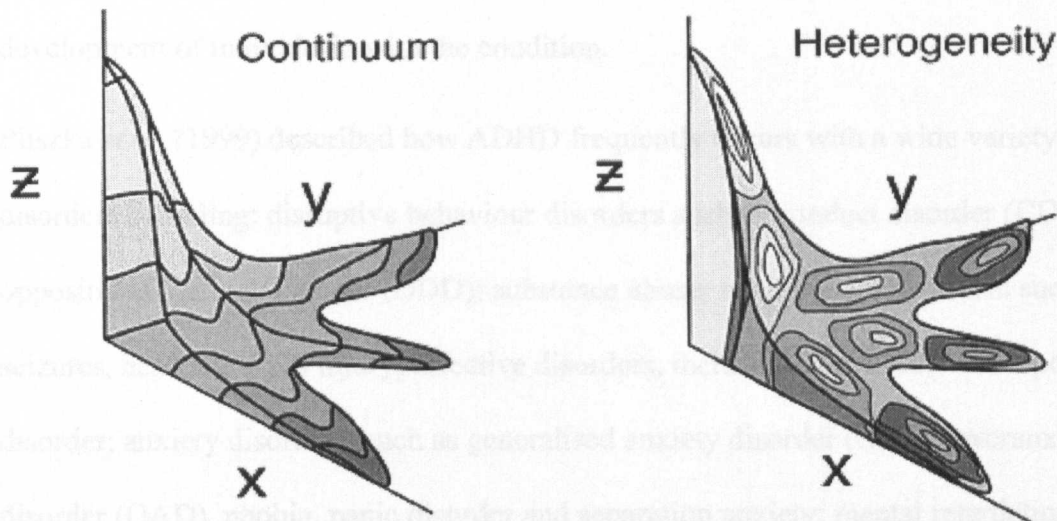
- f) often blurts out answers before questions have been completed
 - g) often has difficulty awaiting turn
 - h) often interrupts or intrudes on others (e.g. butts into conversations or games)
- (DSM IV, APA, 1994, pp. 83-85).

To meet DSM IV criteria some of these symptoms must have been present before the age of 7 years, some impairment from the symptoms must be present in two or more settings, (e.g. both school and home), the symptoms must cause impairment in social, academic or occupational functioning, and symptoms must not be accounted for by another mental disorder.

It has been proposed that DSM IV provides the most comprehensive and reliable diagnostic distinction to date, particularly for the identification of inattentive and combined subtypes (Morgan *et al.*, 1996). Despite clear differences between the inattentive and combined subtypes there remains strong evidence that they share broader neuropsychological deficits, such as deficits in vigilance and effort functions (Nigg *et al.*, 2002). This supports their classification as subtypes under a broader ADHD category rather than as distinct disorders. However, further debate has focused on the distinction between inattentive and hyperactive subtypes. It has been suggested that these groups not only differ in terms of hyperactivity, but also differ in degrees of impulsivity, inhibitory control, conduct problems, social competence, and emotional confidence (Barkley *et al.*, 1990; Cantell & Baker, 1992; Edlebrock *et al.*, 1984; Hynd *et al.*, 1991; King & Young, 1982; Lahey *et al.*, 1984). However, while inattentive and hyperactive subtypes show clear differences some overlap of these symptoms for hyperactive and combined subtypes appears to occur. In particular the combined subtype, like the hyperactive group, show signs of impulsive and inhibitory deficits that are not seen in the inattentive subtype (Nigg *et al.*, 2002). Barkley (1997c) suggested that hyperactive and impulsive symptoms emerge in early childhood, but that inattentive problems can emerge later in development (Applegate *et al.*, 1997; Loeber *et al.*, 1992).

However, it is important to note that debate surrounds the categorisation of this disorder according to such criteria. It has been argued that the profiles and differences in the nature and degree of symptoms are more suggestive of a continuum of problems (Levy *et al.*, 1997). Todd (2000) proposed that categorisation leads to 'fundamental misconceptualizations' about the nature of the disorder, referring to results of latent analysis twin studies to support the argument that ADHD represents the extreme end of a scale of inattention and hyperactivity-impulsivity, as represented by continuums such as the Attention Problems (AP) scale of Achenbach (1977). Todd argued that a continuum model can better account for the wide ranging severity of symptoms seen in children with

ADHD and the differences in varying patterns of comorbidity. Todd concluded that there are at least two continua of problematic behaviours seen in the general population (inattention, impulsivity/hyperactivity) and that the children who fit the criteria for ADHD can be observed at more extreme points along these continua. Todd's (2000) general model illustrating the difference between such multiple heterogeneity and continuum views is shown in Figure 2.



'Two general models illustrate how both continuum and multiple heterogeneity genetic models can explain the distribution of symptoms for a disorder in the general population. For the case of attention-deficit/hyperactivity disorder, the axes might be defined as Z = prevalence, X = inattentive symptoms, and Y = hyperactive-impulsive symptoms. The continuum model resembles a lava flow, where there are smooth transitions in genetic risk to the extreme DSM-IV subtypes (represented by the 3 dark-colored ends of the distributions). For the heterogeneity model, the same distribution resembles a piece of cloisonné in which distinct genetic risk factors contribute to different parts of the observed distribution of phenotypes.'

Figure 2. Todd's (2000) continuum and heterogeneity models of ADHD.

2.1.2 Co-morbid Disorders

Co-morbidity refers to the situation where an individual presents two (or sometimes more) disorders at once. A co-occurring disorder may be directly related to the primary disorder, or it may occur independently. There is considerable debate as to the ability to

identify which disorder, if any, is primary. There is a high rate of co-morbidity in children with ADHD, with Train (2000) estimating that up to 70 per cent of children with ADHD also have a co-occurring condition. Emotional, behavioural and cognitive disturbances that are not directly associated with ADHD are common and mean that individuals with ADHD frequently meet the criteria for a range of additional disorders. This has probably contributed greatly to many of the difficulties in identifying and diagnosing ADHD and has certainly complicated attempts to understand the cognitive development of individuals with the condition.

Pliszka *et al.* (1999) described how ADHD frequently occurs with a wide variety of other disorders including: disruptive behaviour disorders such as conduct disorder (CD) and oppositional defiant disorder (ODD); substance abuse; neurological disorders such as seizures, head and CNS injury; affective disorders, including depression and bipolar disorder; anxiety disorders, such as generalised anxiety disorder (GAD), overanxious disorder (OAD), phobia, panic disorder and separation anxiety; mental retardation and pervasive developmental disorders, including Asperger's Syndrome, autistic spectrum disorders, childhood disintegrative disorder, Rett's disorder and pervasive developmental disorder not otherwise specified (PDD-NOS). Co-morbid disorders also include learning disorders; reading disorders; developmental co-ordination disorder (DCD), semantic pragmatic disorder; medical disorders, including allergies, asthma, hyperthyroidism and otitis media (ear infection); tics, including chronic tic disorder and Tourette's syndrome, and obsessive-compulsive disorders (OCD).

Aggressive, antisocial and oppositional behaviour disorders are those that occur most frequently with ADHD, particularly in the combined subtype (Pliszka *et al.* 1999).

Tannock (1998) estimated that between 40 per cent and 90 per cent of children with ADHD also reach the criteria for CD and ODD. These occur to such an extent that there has been frequent debate as to whether ADHD and CDs should be seen as distinct

disorders or a unitary antisocial behaviour disorder. There is extensive research that indicates that these conditions are distinct (Hinshaw, 1987). However, it appears that these may be inter-related disorders. ADHD certainly appears to be a risk factor for ODD and CDs. It has been illustrated that while many young children with ADHD do not exhibit conduct related problems, as they grow older the likelihood that they will develop antisocial behaviours increases (Robin, 1998). Indeed, researchers have often reported that over 50 per cent of pre adolescent children who have ODD and/or CD also have ADHD (Klein *et al.*, 1997; Pliszka *et al.*, 1999; Szatmari *et al.*, 1989). Substance abuse is yet another common problem for those with ADHD and CD.

Mood disorders are most commonly associated with the inattentive subtype of ADHD but are also commonly found with the combined subtype. Dysthymia, major depression, bipolar disorder, anxiety disorders, panic disorder, social phobias and obsessive compulsive disorder are frequently diagnosed as co-occurring disorders.

Two of the most debilitating disorders to co-occur with ADHD are learning disability (LD) and speech or communication disorders. Both of these disorders result in underachievement, poor self-esteem and isolation. This can seriously confuse the identification of ADHD and will often have important implications for the effectiveness of treatment strategies such as behaviour management and counselling. Often treatments and diagnosis of LD or communication disorders will result in failure to identify or effectively treat co morbid ADHD. The co-occurrence of LD and communication disorder also increases the chance of social exclusion and removal from mainstream academic institutions.

2.1.3 Cognitive Impairment

There are many suggested cognitive deficits associated with ADHD. Theorists and practitioners have yet to form a consensus on their exact nature and how they inter-relate. Historically, emphasis was on impairment of attentional resources. Individuals with

ADHD have problems of selective attention, they respond to irrelevant stimuli and appear to have difficulties identifying and focusing on relevant situational stimuli. The disorder is also characterised by problems of sustained attention.

However, later research has focused on lack of self regulation and problems with stopping inappropriate behaviours or responses. Douglas (1984) described how the tasks that children with ADHD typically fail are those requiring control of inhibitory mechanisms. Douglas argued that these children appear to lack the ability to suppress an immediate response so that the correct response can be thought about and then executed. DSM-IV (American Psychiatric Association, 1994) attempted to take into account both of these approaches and suggested that executive control, including inhibition, is a central problem for individuals with the predominantly hyperactive-impulsive subtype, while limited attentional resources seem to be a more central problem for those with the predominantly inattentive subtype.

2.1.4 Executive Function

Both inhibition and attention are thought to be closely involved in the concept of executive function (EF). It is evident that a common premise in much of the literature concerning the nature of ADHD is that central to the disorder is some form of EF deficit. It has been well documented that individuals with ADHD perform poorly on tests that have been designed to test EF in comparison to controls (Pennington & Ozonoff, 1996). Thus the questions arise: what is EF and why is it important for understanding the cognitive features of ADHD?

In order to examine the relationship between EF and ADHD in more detail it is necessary to look closely at the definition of executive function. As yet there is no universally agreed definition despite many attempts. Sergeant *et al.* (2002) reported that there are currently thirty-three definitions of EF. In general, accounts have focused on the cognitive processes that facilitate strategic planning for goal directed activities.

Researchers have frequently expressed the view that EF involves reasoned, reflective planning and execution of behaviours and responses. Several abilities and skills are all thought to be essential: to form a mental representation (Pennington & Ozonoff, 1996; Welsh & Pennington, 1988); to use forethought and hindsight (Barkley, 1998; Hughes *et al.*, 1994; Ozonoff *et al.*, 1991; Stuss & Benson, 1987); to inhibit a prepotent response (Barkley, 1998; Dehaene & Changeux, 1991; Kimberg & Farah, 1993; Levine *et al.*, 1992; Ozonoff *et al.*, 1991; Pennington & Ozonoff, 1996; Russell *et al.*, 1999; Welsh & Pennington, 1988); to retain context relevant information in working memory (Barkley, 1998; Ozonoff *et al.*, 1991; Pennington & Ozonoff, 1996; Russell *et al.*, 1999); to resist interference from task irrelevant information (Hughes *et al.*, 1994.; Pennington & Ozonoff, 1996; Barkley 1998); and attentional flexibility and adaptive problem solving (Stuss & Benson, 1986; Ozonoff *et al.*, 1991; Pennington & Ozonoff, 1996).

These executive skills are often described as interrelated, and hierarchically organised (Glosser & Goodglass, 1990; Hughes *et al.*, 1994; Stuss & Benson, 1986). Barkley (1998) suggested that EF requires four main activities that facilitate related executive processes. These four main activities are working memory, internalization of self directed speech, emotional and motivational control and control of level of arousal, and lastly reconstitution. Working memory, (the ability to hold information in mind while working on it), is believed to be crucial for goal directed activity as it facilitates hindsight, forethought, preparation and the ability to copy the behaviour of others. Internalization of self directed speech is thought to act as a guide and facilitator of self-regulation, allowing self-reflection, self-questioning, the ability to follow rules and instructions and to construct 'meta-rules'. Control of emotion, motivation and arousal levels is said to be crucial for enabling delay and alteration of inappropriate emotional reactions, and for facilitating socially acceptable behaviour. Reconstitution is described as the ability to break down observed behaviours and to combine parts of behaviours into new actions. This allows the development of planned behaviours, a greater degree of fluency,

flexibility and creativity. It should therefore also allow adaptive behaviour, novel behaviour and problem solving (Barkley 1998).

Barkley (1998) echoed Vygotsky in making the claim that in early development these types of executive functions are external. The development of language is described as essential as the young child talks aloud to guide themselves and to aid memory. As the child grows the 'inner voice' develops, therefore these abilities are said to become internalized and thus private. Although such ideas are not entirely original, Barkley was almost unique in referring to internalization of cognitive processes whilst providing a definition of executive function. This account also has implications for the importance of early language acquisition. It is interesting to note anecdotal reports that many children with ADHD had early experience of speech or language difficulties requiring therapy, and questions have arisen about the extent to which these children develop an inner voice. This may have particular relevance for the study of context effects and ADHD, and the way in which contexts are structured.

2.1.5 Empirical Support for EF Deficits in ADHD

It has been argued that the types of problems exhibited by individuals with ADHD are almost all executive, or rely on executive processes (Barkley, 1996b; Conners & Wells, 1986; Douglas, 1983; Schachar *et al.*, 1993). Ozonoff and Jensen (1999) described ADHD as a condition characterised by deficits in the executive functions of flexibility, set maintenance, organisation, planning and working memory.

Claims of impaired executive abilities in ADHD are supported by findings that individuals with ADHD exhibit poorer performance on tests designed to measure EF than controls. Such tasks include:

- the Tower of Hanoi task, designed by Edouard Lucas in 1883, a rule based problem solving task with the objective of transferring a tower of disks across pegs in a strategically planned format (Aman *et al.*, 1998). The order in which participants

arrange the disks on the last peg must mirror their location on the first peg.

Participants must achieve this in a minimum number of moves. They must never move more than one disk at one time and never place a larger disk on top of a smaller one. The task is demanding in terms of verbal ability and working memory;

- the Stroop task (Stroop, 1935) a task requiring participants to resist interference and inhibit the urge to read a word in order to say the colour of ink the word is printed in (Barkley *et al.*, 1992);
- Go-NoGo tasks, where participants must engage or withhold a specific motor response according to different visual and auditory signals (Grodzinsky & Diamond, 1992);
- Kagan's Matching Familiar Figures Test (MFFT), where participants must select the identical picture to a sample picture from a selection of very similar items (Boucugnani & Jones, 1989). Performance on this measure has been found to correlate with IQ scores (Milich & Kramer, 1984; Schachar & Logan, 1990). This test, like the majority of the other tests of EF, incorporates a substantial reliance on working memory and various forms of attention (Kelly, 2000);
- Trail Making Test Part B (from the Halstead-Reitan Neuropsychological Test Battery, Reitan, 1986), requiring immediate recognition of the symbolic significance of numbers and/or letters, and flexibility in integrating them in a series under strict time limitations (Gorestein *et al.*, 1989);
- Stopping tasks, requiring participants to stop an ongoing prepotent response (Hopkins *et al.*, 1979);
- Anti-Saccade tasks where participants must resist looking in the direction of distractor stimuli (Lavoie & Charlebois, 1994);

- Conflict Motor Tasks requiring participants to execute various responses to commands where physical characteristics are "in conflict" with desired responses (Lufi *et al.* , 1990);
- NEPSY inhibition, part of a battery of tests where participants are asked to inhibit motor activity in situations where distracting stimuli are presented (Pennington *et al.*, 1993);
- Sequential Memory tasks and Self Ordered Pointing tasks, working memory tasks where participants are required to select a different stimulus across trials so that no stimulus is selected more than once (Reardon & Naglieri, 1992; Weyandt & Willis, 1994).

Pennington and Ozonoff (1996) reported that for fifteen out of eighteen studies of EF, individuals with ADHD performed significantly worse than controls on 67 per cent of EF measures, and almost as well as controls on non executive tasks (such as verbal tasks). The most striking effects have been found on the Tower of Hanoi, MFFT, Trailmaking Test Part B, and Stroop test (Pennington & Ozonoff, 1996). Tant and Douglas (1982) compared individuals with ADHD to individuals with Learning Disabilities on a modification of the Twenty Question Test and found that individuals with ADHD were the poorest problem solvers. O'Neill and Douglas (1991) observed poorer study skills and use of strategies for individuals with ADHD compared to controls. And Hamlett *et al.* (1987) observed that individuals with ADHD had particular problems in providing descriptions of strategies and instructions. August (1987), Benezra and Douglas (1988) and McGee *et al.* (1989) also found that although individuals with ADHD performed satisfactorily on simple tasks, those tasks on which they were significantly poorer were tasks requiring implementation of strategies. All of these studies provide support for a general executive dysfunction in ADHD.

2.2 Neurology Associated with EF and ADHD

2.2.1 The Frontal Metaphor

Further evidence that has promoted claims for a link between the disorder of ADHD and executive dysfunction has come from neurological research. Frontal, in particular prefrontal, regions of the brain have been implicated in the development and facilitation of EFs. Pennington and Ozonoff (1996) presented a comprehensive account of the hypothesised link between EF and the prefrontal cortex. Studies of adult neuropsychology have been particularly influential. Impairment of many processes associated with strategic goal focused behaviours has followed frontal damage and lesions. Pennington and Ozonoff cited Fuster (1989), Kolb and Winshaw (1990), Shallice (1988), and Stuss and Benson (1986), who had all reported problems of perseveration, persistence, intrusion of task irrelevant behaviours, lack of initiative, and failure to achieve goals following frontal lesions. In addition, frontal damage or lesions have produced problems with social and emotional behaviour.

However, EF deficits have also been observed following damage or abnormalities in brain regions other than the prefrontal cortex. Pennington and Ozonoff (1996) noted that both Parkinson's and Huntington's Diseases, characterised by deficits of EF, have been associated with the basal ganglia, an area of the brain neuroanatomically linked to the prefrontal cortex but essentially not a part of it.

Clearly many of the behaviours associated with executive dysfunction and frontal lobe damage are those which typify ADHD and there is a wealth of neurological evidence in support of frontal lobe dysfunction in ADHD (Barkley, 1994; Barkley, 1996b; Barkley, 1998; Tannock, 1998). Lesions or injury in this area have been seen to produce ADHD like behaviours, including lack of inhibitory control, disorganisation and problems of planning, poor regulation of emotion, and shortened attention span, (Fuster, 1989; Grattan & Eslinger, 1990; Levin *et al.*, 1991; Stuss & Benson, 1986).

Several researchers have also noted significant levels of underactivity in the frontal areas of the brains of individuals with ADHD (Benton, 1991; Gualtieri & Hicks, 1978; Heilman *et al.*, 1991; Mattes, 1980; Pontius, 1973; Rosenthal & Allen, 1978; Stamm & Kreder, 1979; Zametkin & Rapoport, 1987). Neuro-imaging has shown that individuals with ADHD tend to have decreased blood flow from the prefrontal cortex to the prefrontal lobes (Lou *et al.*, 1984). Lou *et al.* found that the basal ganglia, closely interconnected with the prefrontal cortex, was the locus of reduced blood flow. The basal ganglia connection to the right prefrontal cortex has also been found to be smaller in children with ADHD (Aylward *et al.*, 1996; Castellanos *et al.*, 1996; Singer *et al.*, 1993). Barkley (1998) claimed that these are important findings as the caudate nucleus and the globus pallidus areas of the basal ganglia are believed to be important in resistance of automated responses (inhibition of a prepotent response) and in allowing more in depth consideration of a situation (stop and think mechanism).

Studies of ADHD in adulthood using electrophysiology (Ferguson & Rapoport, 1983; Hastings & Barkley, 1978; Rosenthal & Allen, 1978; Ross & Ross, 1982), and PET scanning have also indicated diminished cerebral glucose utilization in right frontal areas (Ernst *et al.*, 1994; Zametkin *et al.*, 1990). Right hemisphere differences were observed by Hynd *et al.* (1990; 1991) using MRI scans. Pennington and Ozonoff (1996) referred directly to the hypothesised association between the right frontal lobe and measures of sustained attention, claiming that such neuro-anatomical differences are theoretically relevant.

Further support for the claim that ADHD symptoms arise from underactivity in frontal areas comes from the finding that individuals with ADHD respond in a particular way to certain pharmacological interventions. In particular stimulant medication has been shown to increase brain activity in areas that were previously underactive, predominantly the frontal lobes.

2.2.2 Medical Interventions for ADHD

Stimulant medications used in the treatment of ADHD include methylphenidate (Ritalin, Equasym, Ritalin S-R), which is the most widely used stimulant, pemoline (Cylert, Volital), and *d*-amphetamine (Dexedrine) (Barkley, 1990). These drugs act quickly, within about thirty minutes of ingestion, by increasing arousal of the central nervous system thereby activating areas of underactivity. Ritalin, Equasym and Dexedrine are effective for approximately 3-4 hours, Cylert and the sustained release methylphenidate such as Ritalin S-R for approximately 6-8 hours. These medications can be stopped quickly without inducing any medical complications, however the increase in irritability and hyperactivity that this may cause can be of concern. These medications do not cause illegal drug abuse or lead to addiction and they can be taken throughout childhood, typically from the age of 6 years, and into adolescence and adulthood. These drugs are administered to improve attention and decrease hyperactivity, impulsivity and distractibility. They can aid ability to stay on task and to focus, to follow directions and to organise and control thoughts and actions. Barkley (1977) found that stimulant medications led to an average improvement of ADHD symptoms of between 73 per cent and 77 per cent. In particular, stimulant medication has been seen to improve vigilance and attention, memory, impulse control and motor skills (Barkley, 1977; Gadow, 1986). Stimulant medication has also been seen to reduce problems on tests of inhibition, such as the Stopping task (Aman *et al.*, 1996; Schachar & Logan, 1990; Schachar *et al.*, 1993). However there are associated side effects and these include lack of appetite, trouble falling asleep, stomach aches, irritability and emotional sensitivity, and changes in pulse rate and blood pressure. Furthermore these medications may bring the onset of tics.

Tricyclic Antidepressants such as imipramine (Tofranil), desimipramine (Pertofran), amitriptyline (Elavil, Endep), nortriptyline (Pamelor, Aventyl) and clomipramine (Anafranil) traditionally used to treat depression are widely used in the treatment of ADHD and associated disorders such as anxiety, bedwetting, some sleep disorders and

obsessive compulsive disorder (OCD). These medications reduce hyperactivity, inattention and impulsivity in addition to depression, anxiety, and compulsions. As with the stimulant medications stopping these medication quickly is not dangerous but unlike the stimulants this may cause feelings of illness including sadness, trouble sleeping, headache, muscle aches, stomach ache and nausea. Side effects may include constipation, rashes, dizziness, nausea, changes in blood pressure, blurred vision, tics, dry mouth, loss of appetite, sleepiness, irritability and nightmares.

Sometimes medications that lower blood pressure, such as clonidine, (Catapress, Dixarit), are prescribed for individuals with ADHD. They have also been used in the treatment of Tourette Syndrome, mania and aggression and to reduce drug withdrawal effects. These medications are effective at decreasing hyperactivity, impulsivity, irritability, aggression and anger and tics. They are also used to help address problems with sleep disturbance and frustration. These medications are sometimes used alongside stimulant medication, however the effects of these medications are accumulative and often not seen for approximately two weeks after achieving a stable dose. These medications must not be stopped suddenly and must be decreased in dosage slowly as this may cause sudden high blood pressure, changes in pulse rate, headache, nervousness, chest pain, cramps, nausea and vomiting, tics and sleep disturbance. Side effects include sleepiness, weight gain, tics, headaches, dizziness, abdominal pain, nausea or vomiting, and depression.

2.2.3 Neurochemistry

Pennington and Ozonoff (1996) provided a general summary of the possible brain mechanisms involved in ADHD. They described how ADHD appears to be characterised by EF deficits caused by underactivity in frontal regions, likely to have arisen out of either structural and/or biochemical deficits, such as dopamine or norepinephrine depletion, within the prefrontal cortex. Understanding of the neurochemistry involved in ADHD has been promoted by examination of the effects of these medications on the

nervous system. Investigation of the impact of drugs that either increase the availability of neurotransmitters (by increasing the amount that is produced) or decrease the availability of neurotransmitters (by preventing reabsorption) has indicated that the catecholamines of dopamine, epinephrine and norepinephrine are highly implicated in the symptoms of ADHD. It is thought the stimulant drugs used to treat ADHD primarily enhance catecholamine activity, by increasing the levels of dopamine and norepinephrine in the brain and in the prefrontal cortex in particular. It has therefore been hypothesised that dopamine, serotonin and norepinephrine levels are depleted in individuals with ADHD (Barkley, 1990; Shaywitz *et al.*, 1983). Most commonly ADHD has been described as is a disorder of dopamine deficiency. Support for this approach is found in the observation that dopamine suppresses the responsivity of neurons to new stimuli therefore reduced dopamine is likely to result in a greater occurrence of impulsive responses (Diller, 1998). Studies of the dopamine pathways have indicated that one of their functions is to regulate motor activity and incentive learning (Beninger, 1989). The main areas of dopamine and norepinephrine activity are also implicated in motivational learning and responses to reinforcement (Barkley, 1990).

2.2.4 Dopamine

Dopamine pathway activity in particular is highly implicated in the circuits of the brain that facilitate task engagement, attentional flexibility, planning, organisation and working memory and control of motor activity. Dopaminergic receptors are thought to be the main locus of dysfunction (Cook *et al.*, 1995; LaHoste *et al.*, 1996). Research has focused extensively on the role of the D1, D2 and D4 dopamine receptors. The D1 dopamine receptor is thought to be critical for the regulation of pre-frontal regional activity, the D2 dopamine receptor is thought to be important in moderating response to reinforcement and reward mechanisms, while the D4 dopamine receptor is implicated in the function of several different processes as it is located across wide areas of the brain. Dopamine release occurs when a response is reinforced. Johansen *et al.* (2002) therefore viewed

dopamine as a ‘teaching signal’ in that it responds to predicted rules and allows rule-governed behaviour to be learnt. These researchers described how dysfunction of the meso-limbic-cortical dopamine system produces an altered sensitivity to reinforcement resulting in poor attention, hyperactivity and impulsivity. Whereas dysfunction of the nigro-striatal dopamine system was said to result in poor motor control. Sonuga-Barke (2002) also hypothesised that dysfunction of the meso-limbic dopamine pathway could be responsible for delay aversive, hyperactive behaviours, and that the meso-cortical branch of the dopamine system may be responsible for dysregulation of action (motor control) and thought.

However, the extent to which these receptors can be said to be responsible for poor inhibition, hyperactivity and inattention remains controversial and unclear.

However, it is important to acknowledge the complexity of the neurochemical interactions involved and the contradictory nature of many research findings (Pennington & Ozonoff, 1996).

To summarise, ADHD is thought to be a disorder characterised by a range of hyperactive, impulsive and inattentive behaviours. There is mounting evidence for cognitive, and more specifically, EF deficits associated with neuroanatomical characteristics of the disorder.

2.2.5 Problems with the Frontal Metaphor

Criticism has also been levelled at the reliance of many of the tests of EF on the frontal lobe metaphor of EF. This metaphor is in itself controversial. Researchers have stressed that although linked to the prefrontal cortex, EF also involves processes associated with other regions of the brain (Zelazo & Muller, 2002). The frontal metaphor has arisen from the observation that patients with frontal lobe damage exhibit problems associated with EF, but some patients with frontal lobe damage do not show impairments of EF (Shallice & Burgess, 1991). Zelazo and Muller (2002), Goldberg (1995), Luria (1966), and Stuss

and Benson (1986) have all raised concerns over the modular view this metaphor promotes, labelling it 'localizationalist'.

As a result of the frontal metaphor EF measures have been closely linked to neuropsychological measures of frontal lobe function. Neuropsychological measures in general have been criticised as being limited (Houghton *et al.*, 1999). Individuals with frontal lobe damage have frequently exhibited problems on working memory tasks and this in itself may account for poor performance on tests of EF. This has led Pennington *et al.* (1996) to propose that executive function cannot be studied or understood without consideration of the relationship with working memory. In addition, where tests of EF have correlated with frontal lobe damage, relationships have been linked between individual components of tasks rather than overall success on the tests. For example, Levin *et al.* (1994) found a correlation between performance of individuals with frontal lobe damage and initial planning time and number of times rules were broken on the Tower of London task.

2.3 Impairment of Inhibition in ADHD

Issues of discriminant validity have given rise to the need to look in more detail at specific executive profiles that may be associated with developmental disorders such as ADHD. Many theorists propose a core deficit of inhibition in ADHD. Researchers have explored the possibility that impaired inhibition distinguishes ADHD from other developmental disorders such as autism (Ozonoff & Jensen, 1999). This has been somewhat substantiated by findings that the performance of individuals with ADHD differs qualitatively from that of individuals with disorders such as autism on several tests of EF such as the WCST, Stroop and Tower of Hanoi. Significantly these tests rely on working memory and inhibition.

The focus on inhibition as a core feature of ADHD is not a recent development. It has dominated research into the disorder over the last century. Tannock (1998) reviewed the

definitions of ADHD presented over the last 100 years. Still (1902), one of the earliest practitioners to identify and write about the disorder, provided a definition based on a deficit in volitional inhibition. Still believed that this resulted from either a biological predisposition, or pre/post natal brain damage. From the 1940's to the 1950's the focus changed a little as interest developed in the brain damage or dysfunction central to the disorder. However, by the 1960's the focus returned to a deficit of some form of inhibition. This time problems of impulse control and hyperactivity were highlighted. Through the 70's and 80's impulse control was still thought to be a main feature of the disorder, now combined with attentional problems. More recently, during the 1990's and early 2000's, the role of behavioural inhibition and self-regulation have been the focus.

2.3.1 Measures of Inhibition and Research Findings

As reviewed so far, difficulties stopping ongoing responses have been indexed by performance on several EF measures (Barkley *et al.*, 1992; Milich *et al.*, 1994). For example, participants with ADHD were reported to perform significantly less well than controls on thirteen out of the twenty-one studies using the WCST reviewed by Barkley (1997b) and Barkley *et al.* (1992). The most common errors made by participants with ADHD have been perseverative errors (an inability to alter ongoing responses). Van der Meere *et al.* (1988) described how in addition to perseverative errors, individuals with ADHD also exhibit a tendency not to slow responses in order to facilitate a more accurate response. Barkley (1997b) suggested that problems on tests such as the WCST reflect inhibitory dysfunction, in addition to secondary problems of working memory, and highlighted the close interaction between these two processes.

Pennington and Ozonoff (1996) conducted an extensive review of research using measures of EF. These researchers found an extremely strong effect size for tasks they labelled motor inhibition tasks. Commonly these tasks require impulse control and self-

regulation (Berk & Potts, 1991; Korkman & Pesonen, 1994; Milich *et al.*, 1982; Routh & Shroeder, 1976; Sonuga-Barke *et al.*, 1988).

There is mounting research from alternative sources supporting the claim that ADHD is characterised by a deficit of inhibition. Identifying a specific measure of inhibition appears to be a common problem for researchers, however, some of the methods that have been employed are described in this section. Researchers such as Pliszka *et al.* (1997) and Aman *et al.* (1998) have referred to the difficulty of finding a measure that only reflects inhibitory ability, and does not depend on higher cognitive processes. Pliszka *et al.* (1997) searched specifically for a task that correlated with clinical measures of inattention and hyperactivity. They reported considering traditional measures of inhibition, such as the MFFT, but rejected them after concluding that they were confounded by variables such as IQ and a variety of cognitive abilities that affect performance.

Aman *et al.* (1998) outlined tests of inhibition when examining the roles of the frontal lobe compared to the right parietal lobe in ADHD. One such measure commonly used in the study of inhibition is the Go-NoGo task or Stop Signal Paradigm. Pliszka *et al.* (1997) eventually settled on the Stop Signal Paradigm, originally developed by Logan *et al.* (1984), as a measure of inhibitory control. They argued that it was free of many confounds associated with other measures of executive function.

The following sections review in more detail some of the tools designed to assess inhibition and some of the research findings.

2.3.2 EF measures used to assess inhibition: The Stop Signal and the Change Signal Task

The Stop Signal Task is reported to measure the ability to stop an ongoing response and the speed of the inhibitory process (the outcome and the time taken to achieve this). The task is often presented on computer. Participants are required to respond to stimuli, such

as by pressing a button corresponding to the stimulus presented. However, on approximately 25 per cent of trials a stop signal, usually a tone, is presented. When the stop signal is presented the participant must inhibit their primary task response.

Researchers such as Schachar and Logan (1990) and Schachar *et al.* (1993) have also used a modification of the Stop Signal Task known as the 'Change Signal Paradigm' to assess inhibition. This requires the participant to stop a prepotent response and then to switch to an alternative response. The test measures stop signal response time and the time taken to switch to the alternative response.

2.3.3 Performance on The Stop Signal Task and The Change Signal Task

Participants with ADHD perform significantly worse than comparison groups on Stop Signal Tasks (Pennington & Ozonoff, 1996; Schachar & Logan, 1990). They have repeatedly been slower to respond to a stop signal, less likely to inhibit a response and more variable in inhibitory responding (Oosterlaan *et al.*, 1998a; 1998b). These findings have been used as indicators of poor motor inhibition (Barkley, 1994, 1996, 1997b). Tannock *et al.* (1989) also reported that the Stop Signal Task presented significant difficulties for children with ADHD. However, Tannock *et al.* (1989) found that when given methylphenidate (Ritalin) this performance decrement was reduced.

On Change Signal Tasks individuals with ADHD have been found to be slower to inhibit the prepotent response after the stop signal, and slower to re engage in the alternative response than controls (Schachar *et al.*, 1995). Schachar *et al.*'s results indicated that participants with pervasive ADHD showed significantly less inhibitory control than typically developing controls. This difference was attributed to slower inhibitory process. Participants with ADHD also exhibited reduced ability to re engage in the alternative response, their response times were longer and variability in responding greater.

However, it is important to note that their primary task responding was also slower and

more variable. It was concluded that participants with ADHD had both an inhibitory and re-engagement deficit.

Oosterlaan and Sergeant (1998a; 1998b) also studied inhibitory control in ADHD using a change signal task. Participants with ADHD again performed in a way suggestive of inhibitory problems and poor response re engagement. However, impaired performance was not unique to participants with ADHD. Participants with other disruptive disorders also showed inhibitory and re-engagement problems. However, Schachar *et al.* (1995) claimed that deficient inhibitory control not only distinguished children with ADHD from both typically developing children, it also distinguished them from those with other developmental disorders such as CD. Although children with CD have also displayed problems of inhibition, their performance has not been found to differ significantly from that of typically developing children (Schachar & Logan, 1990a). The performance of children with ADHD on inhibitory measures such as the stop signal has also been seen to be significantly worse than the performance of children with co-morbid ADHD and CD (Schachar & Logan, 1990a). This finding was re-investigated and replicated by Schachar *et al.* (2000) using a tracking version of the Stop Signal Task. Participants with ADHD were again significantly slower than both typically developing participants and participants with CD to stop an ongoing action. Results were not correlated with age, IQ or sex.

2.3.4 Performance on Go-NoGo Tasks

Individuals with ADHD have frequently been reported to fail a form of Stop Signal Task known as the Go-NoGo paradigm (Laboni *et al.*, 1995; Milich *et al.*, 1994; Oosterlaan & Sergeant, 1995, 1996; Quay, 1997; Schachar & Logan, 1990; Schachar *et al.*, 1993, 1995; Shue & Douglas, 1989; Trommer *et al.*, 1988). This reflects the inability of participants with ADHD to withhold a response (Shue & Douglas, 1992).

2.3.5 EF measures used to assess inhibition: The Stroop Test

Lovejoy et al. (1999) identified the Stroop Test as being sensitive to lack of inhibitory control and impulsivity. However, performance on some traditional manipulations of the Stroop Test can be confounded by reading ability as the Stroop Test requires participants to read different coloured words. As a result, versions of the Stroop Test that do not rely on reading ability have been developed. Archibald and Kerns (1999) used the Sun Moon Stroop and the Fruit Stroop (a modification of Santostefano's 1988 Fruit Distraction Task). These modifications of the Stroop Test avoid reliance on verbal and reading ability. The Fruit Stroop, in addition, avoids the problem of counterfactual reasoning.

2.3.6 Performance on the Stroop Test

Measures of interference control and resistance to distraction, such as the Stroop colour word test, have also revealed problems of inhibition in ADHD (Krener *et al.*, 1993; Leung & Connolly, 1996; Pennington *et al.*, 1993). Barkley (1999) reviewed eleven such studies, ten of which demonstrated that participants with ADHD take more time and make more errors during the interference component of the test (where participants are required to say the colour of the ink and not the word printed). Barkley argued that the consistency of findings using this measure, despite different methodological manipulations, is striking, and provides strong support for an inhibitory deficit.

2.3.7 Measures of inhibition: The Anti Saccade Task

Aman *et al.* (1998) used an Anti Saccade Task as a measure of inhibitory control. This was again computerised. This task requires participants to inhibit a reflexive response, an eye saccade, when a visual stimulus was presented upon a screen. Participants must look at the screen but on presentation of a cue were to inhibit the response to look at the screen, and were to look in the opposite direction.

2.3.8 Performance on Anti Saccade Tasks

Anti Saccade Tasks have often been used to illustrate problems of inhibitory control. For example, Roberts *et al.* (1994) measured participants' ability to resist looking at distracting stimuli as a reflection of inhibitory control and concluded that the ability to delay the looking response was significantly poorer in participants with ADHD. Ross *et al.* (1994) also found that participants with ADHD had difficulty inhibiting eye movement and often looked straight to a new stimulus. And Aman *et al.* (1998) concluded that the anti saccade measures of inhibition was one on which participants with ADHD were most impaired.

2.3.9 Measures of inhibition: The Detour Reaching Box Test

Hughes (1998) utilised two measures of inhibitory control specifically to test the abilities of children. These were the Detour Reaching Box Test (Hughes & Russell 1993) and Luria's 'fist and finger' hand game. For the Detour Reaching Box Test the child must reach through a window cut in a box to try to obtain a marble. This action results in the marble falling out of reach. This procedure is repeated several times until the child becomes aware that he/she cannot reach the marble directly. During this procedure a yellow light has been visible on the box. The child's attention is now drawn to this light and he/she is told that when the yellow light is showing he/she cannot reach through the window. Instead he/she must turn a knob on the box and this will release the marble. The child is then shown a green light and told that when the green light is showing he/she must push a switch on the left of the box. This will then allow him/her to reach directly through the window without the marble falling as it did before.

2.3.10 Measures of inhibition: Luria's Hand Game

The second measure of inhibitory control used by Hughes was Luria's Hand Game. During testing both the child and the experimenter place their hands behind their backs. In an 'imitative condition' the child is asked to imitate the experimenter as they point a

finger or model a fist action. In a 'conflict condition' the child is asked to produce the opposite action to that of the experimenter. This task does not rely heavily on verbal ability or memory load and can be made into a game.

2.3.11 Playroom Observation Procedures: Behavioural Observations

Observation procedures have often been reported to identify differences between children with and without ADHD (Barkley *et al.*, 1991; Breen, 1989; Campbell *et al.*, 1986; Milich *et al.*, 1982). Observations of higher levels of motor activity (Luk, 1985; Teicher *et al.*, 1996) and higher levels of verbal activity in children with ADHD (Barkley *et al.*, 1983; Barkley *et al.*, 1990; Berk & Potts, 1991; Copeland, 1979; Copeland & Weissbord, 1978) have been interpreted as an indication of poor inhibitory control. Such observations often involve the use of Behaviour Rating Scales. Barkley (1999) claimed that parent and teacher ratings of hyperactive and impulsive behaviour can be a useful indicator of the types of behaviour that distinguish children with ADHD from comparison groups and typically developing children. In particular the responses given in these rating scales have highlighted poor impulse control as a common feature of the disorder.

The observation method may reflect more naturalistic behaviours and abilities. Several researchers have used observation measures in the study of participants with hyperactivity and ADHD (Alberts & van der Meere, 1992; Bakeman & Gottman, 1987; Mason & Redeker, 1993; Porrino *et al.*, 1983). Antrop *et al.* (2000) used such a procedure to observe the effects of delay on children with ADHD in order to investigate their inhibitory abilities. The behaviours of participants with ADHD were observed across a period of delay that lasted 15 minutes. During this period participants were either left alone or given a video to watch. Independent observers coded behaviour during this period according to a 10-second interval procedure. Behaviour was coded as 1: gross motor activity (working, running, climbing etc), 2: minor motor activity (movements of

arms, legs, head etc), 3: sounds, 4: self-occupation (touching objects, playing etc), and 5: situation specific (leaving the room, going out of sight).

Results indicated that when children were asked to wait without the video children with ADHD displayed significantly more behaviour that was classed as 'stimulation seeking'. These findings were used in support of the claim that in conditions of low stimulation children with ADHD act hyperactively in order to stimulate themselves and counteract their lack of arousal.

This observation procedure is similar to that used by Handen *et al.* (1998) in all measures. Handen *et al.* (1998) tested children's inhibitory abilities using a naturalistic Playroom Observation Procedure. This was based upon the earlier work of Routh and Schroeder (1976) and later Roberts (1984, 1990) who used a playroom observation procedure to distinguish children with hyperactivity from typically developing children. Handen *et al.* (1998) adapted Roberts' (1984) procedure and assessed ADHD children's free play and then their performance on a restricted academic task whilst in the presence of distractor toys. During the free play session children's behaviours when left alone in a room with twelve toys (varying in levels of 'femininity/masculinity') were recorded and coded as the per centage of 10-second intervals spent:

1. acting intensely: inappropriate or excessively rigorous physical activity such as throwing toys, running about, yelling, etc;
2. vocally: any sound voluntarily emitted;
3. moving about: any gross motor movement such as taking one or more steps, moving bottom whilst sitting and so on;
4. playing with non toys: such as door knobs, table etc, but only coded if the child also failed to play with normal toys during the same 10 second interval;
5. not involved with toys: neither playing with a toy or a non-toy;
6. picking up toys: actively picking up or touching a new toy, measures shift in interest

7. leaving toys: leaving alone a toy which had been in their possession;
8. playing with toys: span of time a toy was in their possession.

During the restricted academic task the child was again placed in the same room. They were left alone to complete an underlining or cancellation task. In the same room was placed a table of different toys. Each child was instructed to work on the task for ten minutes whilst the adult left the room. They were told not to touch the toys and that the adult would be back in ten minutes. Again a 10-second recording system was used to calculate the percentage of time spent engaging in different behaviours and to measure distractibility. The following classifications were coded:

1. on-task behaviour: no more than three seconds spent off task, the rest of the time spent focusing on the task;
2. distracted: if the child looked away from the task for more than three seconds;
3. touching toys: whenever a toy was touched at any point;
4. fidgeting: whenever repetitive, restless motor movements were observed which were purposeless;
5. out of seat: if child's bottom left the seat at any point.

Using this approach Handen *et al.* (1998) concluded that they were able to distinguish children with hyperactivity from typically developing children.

2.3.12 Behavioural Observations: Performance on Temptation and Gratification Paradigms

Analogue studies, which examine children's ability to restrict their behaviour (Luk, 1985) have also shown that children with ADHD have problems of inhibition (Barkley, 1999). Such studies include resistance to temptation paradigms, in which individuals with ADHD have exhibited difficulties resisting a desirable reward they have been told to leave alone until later (Campbell *et al.*, 1982, 1994; Hinshaw *et al.*, 1992, 1995). They also include gratification paradigms, again where individuals with ADHD have exhibited

problems waiting for rewards (Rapport *et al.*, 1986; Schweitzer & Sulzer-Azaroff, 1995). Once again children with ADHD have appeared significantly less able than typically developing children and comparison groups to restrict impulsive behaviour.

2.4 Physiological Evidence

2.4.1 Abnormal Brain Morphology

Neuro-imaging studies have found abnormal brain morphology in areas connected with areas of the cortex that have been shown to affect suppression of automatic responses in primates (Giedd *et al.*, 1994).

2.4.2 Heart Rate Change

Jennings *et al.* (1997) utilised heart rate change as an index of inhibition in an investigation of the EF problems of ADHD. This was based upon the assumption that inhibition of action slows the heartbeat. The slowing of the heart rate had also been used as an index of inhibition by Jennings (1992) and van der Meere *et al.* (1991). Jennings *et al.* (1997) aimed to use this measure to provide a description of the process of inhibition rather than evidence of lack of inhibitory ability. Essentially their method measured response rates and performance using a stop signal paradigm. Jennings *et al.* (1997) hypothesised that inhibition latencies would be longer for participants with ADHD due to a failure to maintain anticipatory attention arising from lack of inhibition and failure to respond to a signal for inhibition. This would be indicated by less anticipatory cardiac deceleration before the go signal and less cardiac deceleration after the stop signal.

Jennings *et al.*'s (1997) concluded that younger participants with ADHD exhibited slower and less successful inhibitory reactions. They produced poorer response times when the stop signal appeared soon after the go signal than controls. However, contrary to their original hypothesis, heart rate was not found to be faster in participants with ADHD. In contrast typically developing participants had faster heart rates. There were no significant differences in heart rate changes across groups.

2.5 Theories of ADHD, Research Findings and Interventions:

Implications for the Study of Context Effects in ADHD

The material presented in sections 2.1 to 2.4 aims to shed light on the nature of ADHD in order to examine whether children with the disorder are likely to be subject to the effects of context. This material would seem to suggest that individuals with ADHD experience pervasive neurological problems that result in specific impairments of executive function and inhibitory control. The neurological underpinning of these deficits would imply that these cognitive processes will be significantly impaired across domains and contexts.

However, there is evidence that suggests that context may have an important role to play in mediating the interaction between these neurological deficits and performance. The following sections outline some of the theories and material that provide support for both sides of this debate.

2.5.1 Evidence for Cognitive Impairment across Contexts: Barkley's Unified Theory of ADHD

One of the most comprehensive theoretical models of ADHD to date, and perhaps the most scrutinised, was put forward by Barkley (1994; 1996b; 1997b). This account is one of the most established theories of ADHD that proposes that the disorder is one of unrelenting neurological and cognitive deficits that persist across contexts. The theory strongly suggested that the performance and behaviour of individuals with ADHD will always be dictated by their underlying cognitive impairments. Barkley's theory of ADHD incorporated findings from a wide variety of sources, particularly cognitive research, neuropsychological research and paediatric practice. It provided a description of both ADHD and the cognitive profile associated with it. The model considered the role of executive dysfunction, and offered an explanation for how a core deficit in a specific executive ability could affect other cognitive processes and domains, such as perception, memory, language and sensation (Barkley, 1997b). This core deficit was one of inhibition

and was attributed to deficiencies of the prefrontal cortex and interconnections with areas such as the striatum (Barkley, 1997b; Castellanos *et al.*, 1994; 1996; Heilman *et al.*, 1991; Lou *et al.*, 1984; 1989; Zametkin *et al.*, 1990).

The processes affected by inhibition were said to be those that assist self-regulation. Inhibition was said to be crucial in allowing an individual to stop and think, providing the delay that allows other executive functions to occur. Inhibition is therefore the mechanism that allows primitive, impulsive responses to the environment to become withheld allowing executive, reflective processing. Inhibition was referred to as the mechanism for allowing consideration of internal information. Consideration of this information allows us to gain a 'sense of time'. It allows consideration of the future in addition to the past and present.

Barkley's (1997b) account offered a new perspective on the role of behavioural inhibition. Barkley proposed that behavioural inhibition consists of three interrelated subtypes of inhibitory process: inhibition of the initial prepotent response; stopping of an ongoing response (providing a delay in the decision to respond); and interference control (Barkley, 1997b). Impairment of these primary inhibitory processes was said to lead to secondary impairments across many cognitive, and particularly executive, mechanisms. In particular, secondary impairments were hypothesised to occur in four areas of executive function: working memory (nonverbal); self-regulation of affect, motivation and arousal; internalisation of speech (verbal working memory); and reconstitution. These were all said to be dependent upon inhibition.

Impairment in the four executive abilities was said in turn to lead to a decrease in self directed activation and regulation and an inability to represent information internally. This has an effect on motor control, motor fluency and motor syntax. Barkley proposed that it follows that if the inhibitory deficit can be reduced or reversed the impairment of

these abilities (those that are hierarchically related to inhibition) should also reduce or disappear.

It was proposed that the regulatory behaviours affected by inhibitory dysfunction are externally guided in childhood. However, throughout development into adulthood these self-regulatory behaviours gradually become internalised and develop into executive abilities. An important feature of the internalisation of these self-regulatory abilities is the development of self-directed speech (Barkley, 1997b). Internal speech acts as an important guide or prompt, reminding the individual what they should be doing and how and when to go about doing it. Development of self directed speech may be delayed in children with ADHD, thus leading to more external speech. In support of this children with ADHD have been observed to talk more to themselves, out loud and to others, and to blurt out verbal responses and make intrusive comments, (APA, 1994; Barkley *et al.*, 1983; Berk & Potts, 1991; Copeland, 1979; Copeland & Weissbrod, 1978; Fuster, 1989; Malone & Swanson, 1993).

2.5.2 Evaluation of Barkley's Unified Theory of ADHD

Barkley's model was particularly effective in accounting for the wide range and variety of research findings, particularly those using measures of EF. Deficits in working memory could account for inability to hold an event in mind, inability to manipulate or act upon events, poor imitation of complex behaviour sequences and lack of hindsight, forethought, anticipatory set, a sense of time and cross-temporal organization of behaviour. Poor self regulation of affect, motivation and arousal could account for poor emotional self control, lack of objectivity and social perspective taking, poor self regulation of drive and motivation, and poor regulation of arousal in the service of goal directed action. Internalisation of speech was said to facilitate description and reflection, and deficits would therefore account for problems with rule-governed behaviour, problem solving and self-questioning, generation of rules and meta-rules and moral reasoning. As

reconstitution determines the analysis and synthesis of behaviour, a deficit would account for problems of verbal fluency and behavioural fluency, goal directed behavioural creativity, behavioural simulation and syntax of behaviour.

Despite accounting for a wide range of research findings the model is vulnerable as it relies heavily on the assumption that inhibition is a primary deficit that gives rise to secondary executive deficits. Evidence for the primacy of disinhibition is less robust. It remains a possibility that inhibition is just one of several executive impairments caused by some wider cognitive deficit. The study of Schachar *et al.* (1995) is important to consider at this point as it is one amongst only a few which looked at the impact of inhibitory dysfunction on secondary executive process. The study can be used as a test of the predictions of Barkley's (1997b) theory.

Schachar *et al.* (1995) examined the effect of inhibitory dysfunction on the ability to alter an action and switch attention and focus on a new response. The re-engagement described by Schachar *et al.* is likely to have required working memory, the ability to hold an event in mind, the ability to manipulate or act upon events, forethought, anticipatory set, a sense of time and cross temporal organisation of behaviour. Barkley's (1997b) model predicts that the individual with ADHD will be impaired in the ability to inhibit the primary response and this will have an effect on the executive abilities described above, thus resulting in poor re-engagement in an alternative response.

In confirmation of this prediction Schachar *et al.*'s findings revealed deficits in both inhibition and response re-engagement. However, contrary to Barkley's (1997b) claims, Schachar *et al.* (1995) failed to find a significant correlation between the time taken to inhibit the primary task response and the time taken to re-engage an alternative response. Thus Schachar *et al.* concluded that these two processes are independent. Several other researchers have also concluded that response inhibition and response re-engagement are independent processes (De Jong *et al.*, 1990; Jennings *et al.*, 1992; Logan & Burkell,

1986; Logan & Cowan, 1984). Despite this finding it remains possible that inhibition facilitates secondary executive functions.

2.5.3 Evidence for Cognitive Impairment across Contexts: Quay's Model

Gray (1982; 1987) posited that there are three interrelated systems that provide the neurophysiological basis of behaviour. These are the Fight/Flight system that responds to unconditioned negative stimuli; the Behavioural Activation System (BAS) that responds to conditioned positive stimuli or where the individual seeks relief from negative stimuli; and the Behavioural Inhibition System (BIS) that responds to conditioned negative stimuli in addition to novel or innate fear stimuli. In particular, the BIS was described as the system responsible for stopping an ongoing response, for an increase in arousal and the focus of attention on environmental cues. It was said to prompt passive avoidance of stimuli or activates the cessation of behaviour that has previously resulted in negative consequences.

This model was utilised by Quay (1988a, 1988b, 1997) in his attempt to account for the symptoms of ADHD. Like Barkley, Quay described ADHD as a neurological disorder that persists across contexts. According to Quay's model, ADHD results from an imbalance between neuropsychological systems of behavioural inhibition and behavioural activation that control responses to signals of punishment and reward. More specifically, Quay attributed ADHD to an impairment of the BIS, which he described as underactive. Quay made the claim that the individual with ADHD is less responsive to conditioned signals of punishment and non reward. These conditioned signals, environmental cues, are those that suggest that negative consequences could occur if the individual does not stop and consider their response.

As Gray's earlier work linked the BIS, BAS and Fight/Flight systems to neurological function and structure, Quay's subsequent model also suggested a neurological basis for

inhibitory impairment. Quay's model claimed that the BIS is dependent upon noradrenergic and serotonergic inputs.

2.5.4 Quay's Model: Evaluation

Quay's model accounts for the individual with ADHD's poor performance on measures of inhibition and offered an explanation for why these individuals appear less deterred by signals of punishment, less able to resist temptation and verbal outbursts and less able to suppress inappropriate behaviour. Quay's model accounted for findings from Anti Saccade Tasks and Stop Signal Paradigms. On Anti Saccade Tasks, such as that of Ross *et al.* (1994), an underactive BIS can account for failure to inhibit eye movements to distractor stimuli. Furthermore, eye saccade tracking paradigms frequently measured the speed of the eye movement to the new stimulus after the original stimulus had disappeared. This has been used to indicate preparation to respond. Researchers such as Sanders (1983) have predicted that inhibitory problems will contribute to problems in preparation to respond. However, despite problems of inhibition, findings from eye tracking tasks have indicated that individuals with ADHD do not have problems in the activation of preparation to respond. Quay's model accounts for this pattern as, despite problems of the BIS, the BAS is said to function efficiently in individuals with ADHD.

Quay described the Stop Signal Task as 'a purer measure of inhibitory control than any that had come before' (1997). This paradigm facilitated direct examination of Quay's claims as it does not include signals of reward, and presents a conditioned signal for non reward, the sort of environmental cue Quay described as triggering the BIS.

Quay's (1993) model can also account for disorders characterised by aggression or anxiety. According to Quay (1993), in direct comparison to ADHD, disorders of anxiety result from an overactive BIS. Conduct problems (CD, ODD) were said to result from dominance of the BAS over the BIS. Aggression was said to result from a combination of an underactive BIS (as with ADHD) in addition to an overactive BAS. Thus, where

individuals with ADHD were thought to be less sensitive to the signals of probable punishment and non reward that trigger the BIS, individuals with CD were said to be overly sensitive to signals of possible reward and non punishment that trigger the BAS. The result of the overactive BAS, when signal of punishment and non reward are present, is the failure of the BIS to interrupt the already triggered BAS.

For individuals with co-occurring ADHD and CD problems inhibiting an ongoing action should be even more exaggerated as the BAS dominates over an already impaired BIS. This was the finding of Matthys *et al.* (1998) using a response perseveration task. However, Matthys *et al.* made the suggestion that poorer performance might only reflect an underactive BIS, and found no discernable evidence for an overactive BAS. In addition, they highlighted the influence of processing limitations, in particular the 'ability to assimilate unattended but potentially relevant information', that may also account for poor inhibition. In order to compare functioning of the BIS and BAS in individuals with ADHD these researchers suggested using separate tasks, one containing reward and the other punishment.

Oosterlaan and Sergeant (1996) set out to fully examine the predictions of Quay's (1988, 1993) model comparing the performance of participants with ADHD to that of aggressive and anxious individuals. The task used was a two choice reaction time task, whereby the participant was presented with a white square on the screen in front of them. This square either appeared to the left or the right of the screen. Participants were to press a button to the right or left of the screen corresponding to where the square had appeared. On some trials, at different intervals after the primary task had started, a tone was presented. Participants had been instructed that on hearing the tone they were to stop pressing the buttons. Mean reaction times on the primary task were measured, as was accuracy of responding. Inhibition was measured in two ways, stop signal reaction time and inhibition function.

According to Quay's model (1988, 1993) participants with ADHD should exhibit a flat inhibition function and slow response times to the stop signal. Anxious participants should have a steeper inhibition function and faster stop signal response times and aggressive participants should perform in a similar way to participants with ADHD. In support of Quay, Oosterlaan and Sergeant 's (1996) results showed a slower inhibitory response and flatter inhibition function for participants with ADHD and aggressive participants. However, contrary to the predictions of Quay's model, the performance of anxious participants did not indicate faster inhibitory processes than typically developing participants, nor did they produce a steeper inhibition function.

Oosterlaan and Sergeant (1996) suggested that signals of punishment and non reward were not significantly pronounced to trigger an overactive BIS in anxious participants. If this were the case then it is also possible that signals of punishment or non reward were not sufficient to prompt inhibition for both individuals with ADHD or individuals suffering from aggression.

However, the Stop Signal Paradigm has also been criticised as being lacking ecological validity, and being boring or irrelevant to everyday functioning and therefore inappropriate for use with children. Furthermore, the participant is warned to look out for the stop signal and told how to respond when they hear it. In contrast, everyday functioning requires the individual to process a much greater number of varied environmental stimuli. They must respond adaptively taking into account many possible response strategies. Their response is very rarely prepared in the way it is with the Stop Signal Task. Being prepared and pre-warned is likely to diminish the need for increased arousal and stimulation, something which the BIS was said to increase.

There have also been findings that do not correspond to the predictions of Quay's model. Pliszka *et al.* (1993) failed to show less sensitivity to conditioned signals for negative consequences. This study examined psychophysiological responses to a classically

conditioned negative stimulus. Participants were presented with an aversive conditioned stimulus. Results showed no significant differences in skin conductance and heart rate change between participants with ADHD, participants with co-morbid ADHD and anxiety and a typically developing comparison group. There were several possible explanations for this finding. First, that individuals with ADHD are no less sensitive to conditioned signals of negative stimuli (in contrast to Quay's claims). Second, that the sample of participants with ADHD was too small and unrepresentative. Third, that differences may occur with operant conditioning rather than classical conditioning (Pliszka *et al.*, 1993). Or fourth, that the psychophysiological measures used did not effectively reflect processes implicated in activation of the BIS. Sensitivity to environmental cues may not be as important in activation of these systems as Quay described. General physiological arousal and other processes may be more important in the functioning of the inhibition system.

2.5.5 Evidence for Cognitive Impairment across Contexts: Information Processing Accounts

Logan (1994), Schachar and Logan (1990), Schachar *et al.* (1993), Schachar *et al.* (2000) have attributed the problems of ADHD to an inefficient information processing. Once again, these processing deficits were hypothesised to occur across contexts. The focus has been on impulsive responding and an inability to inhibit a prepotent response, which were viewed as a single processes in a hierarchically organised system of many executive functions. When combined and integrated (in the correct manner) these executive processes facilitate self-regulation and operation of the information processing system.

Logan (1994) hypothesised that the observed inability to inhibit a prepotent response exhibited by participants with ADHD arises out of either extremely fast response mechanisms or extremely slow processing. In terms of Quay's model this would be a fast BAS or slow BIS. Findings of slower inhibitory processing have been reported by

researchers using Stop Signal Tasks and Continuous Performance Tests. The findings of Schachar and Logan (1990) and Schachar *et al.* (1993) were accounted for by extremely slow inhibitory processing rather than fast responding. It was therefore proposed that individuals with ADHD can inhibit but that this inhibitory process is delayed (Logan, 1994; Schachar & Logan, 1990; Schachar *et al.*, 1993; Schachar *et al.*, 2000).

Additionally, fast activation and slow inhibition may not necessarily be exclusive of one another. ADHD may feature a combination of both, or they may both be part of the same process.

Tannock (1998) also raised the question of whether research findings reflect an inhibitory deficit, or alternatively a speed of processing deficit. She criticised theorists, such as Barkley, for seeking a unitary cognitive deficit within ADHD instead of looking for various deficits and how they might be related.

2.5.6 Information Processing Accounts: Evaluation

Jennings *et al.* (1997) also looked at processing abilities in order to develop an understanding of ADHD. These researchers looked at ability to focus on an unexpected event and to inhibit motor responses related to that event. The hypothesis was posited that environmental signals for inhibition and the need for anticipatory attention should activate central nervous system arousal and facilitate motoric inhibition. They claimed that the purpose of inhibition is to create delay and reallocate resources to allow anticipatory attention and thus preparation for responding.

The results of their study showed children with ADHD to have slower and less successful inhibitory reactions. In an attempt to unravel the implications of their findings Jennings *et al.* (1997) suggested that children with ADHD must exert greater inhibitory effort to achieve the same performance level as that of typically developing children. A compensatory approach was suggested, where greater effort is used to compensate for

poorer abilities. Tasks that these children fail are likely to be those where cognitive demands are greater but that fail to stimulate motivation and effort.

2.5.7 Evidence for Cognitive Impairment across Contexts: The Supervisory Attentional System (SAS)

More recently, Bayliss and Roodenrys (2000) used the model of working memory of Baddeley and Hitch (1974) to account for the persistent executive impairments exhibited across contexts by individuals with ADHD. Baddeley and Hitch's model of working memory described how EFs are controlled by a Central Executive (a limited capacity processing system). The model was later modified to incorporate the supervisory attentional system (SAS) proposed by Norman and Shallice (1986). The control of action was attributed to two processes, Contention Scheduling and the SAS.

Contention scheduling was said to facilitate automatic control of routine activities. It was said to be unconscious, requiring few resources and little attention. Memory of responses to routine or frequently experienced events were said to be stored as schemata. These are activated by conditioned triggers. Contention scheduling was said to be a process that orders schemata and prevents them from competing for cognitive resources using a lateral inhibitory mechanism (Shallice & Burgess, 1991b).

However, for novel events or those involving complex processing the contention scheduling mechanism is modulated by conscious control of the SAS, a resourcefully demanding process. Novel events were thought to introduce conflict between potential schemata and therefore confusion over the most appropriate responses. The SAS is a conflict resolution mechanism, activating the most relevant and appropriate response. The SAS was therefore said to be responsible for selecting the most important environmental stimuli to act upon. It was thought to be a mechanism that stimulates conscious control of action and responses. The SAS would therefore be necessary for the activation of

appropriate responses in situations that involve planning, decision making, error correction, novel responses, difficult actions, and when overcoming habitual responses.

Bayliss and Roodenrys described how poor functioning of the SAS could account for the executive problems in ADHD. Impairment of the SAS would result in inappropriate behaviour, of the sort exhibited by individuals with ADHD. If the SAS does not function normally the operation of contention scheduling becomes problematic and novel responses that are highly activated interrupt routine behaviour.

2.5.8 The Supervisory Attentional System: Evaluation

This model can account for occasions where individuals fail to inhibit prepotent responses and where they fail to adapt easily to new and more appropriate responses.

According to the model the chance of becoming 'stuck' in a response is more likely if the SAS fails to function effectively. Highly activated responses with strong environmental triggers will dominate as the SAS must function effectively in order for a new response to be given priority. The individual with a deficient SAS will have problems selecting new appropriate responses and will revert to an old response (Shallice, 1982). Where strong environmental signals are missing the individual will randomly focus on stimuli to select their responses. This results in the types of irrelevant behaviour and distractibility which are characteristic of ADHD (Shallice, 1982; Shallice & Burgess, 1991b). This can therefore account for perseverative errors (as seen on the Stop Signal Paradigm, Go-NoGo tasks and the CPT).

Initial investigation of this account has revealed the complexity of the model and the relationship between the SAS, contention scheduling and inhibition. Baylis and Roodenrys' (2000) research suggested fractionation of the SAS. These researchers concluded that impairment of a more specific component of the SAS, such as that responsible for inhibitory control, was implicated in ADHD. Further research exploring this relationship and evaluating the model is required.

2.5.9 Evidence for Cognitive Impairment across Contexts: A Disorder of Language Acquisition

This recent account of ADHD has more historical roots. Based upon broader theoretical notions Baird *et al.* (2000) focused on the development of language acquisition in order to account for the development of an inner voice that guides thought and regulates behaviour. One of the first to look at the role of the inner voice was Vygotsky (1962) who stress how, by the process of internalisation external communication becomes internalised to form the inner voice that guides behaviour. This importance of language for self-regulation was later re-emphasised by Luria (1961).

Baird *et al.* concurred with Barkley that ADHD features a central impairment of inhibition that will determine performance and behaviour across contexts. Private speech is eventually anticipatory and central to the planning and execution of tasks (Berk, 1992). Baird *et al.* argued that these unique cognitive features are a side effect of communication. The ability to inhibit is thought to have arisen from advances in human communication. Self-regulation is thought to involve the ability to refer to symbols and to selectively feedback symbolic information (Deacon, 1997). The development of language is thought to have promoted greater social interaction. Social behaviour demands greater self-regulation and ability to maintain attention and selectively choose appropriate responses. Baird *et al.* argued that if human self control is a side effect of language development then it follows that problems of self control, such as in ADHD, are likely to be linked to problems of language acquisition or development. As a consequence Baird *et al.* suggested that problems of self regulation are not likely to be unique to ADHD, rather they described how variation in these types of problem could characterise associated disorders and could account for co-morbidity.

2.5.10 A Disorder of Language Acquisition and Private Speech: Evaluation

Although relatively under-researched there is a large amount of evidence for language related problems in ADHD. Research has been conducted that suggests there is an important association between language, private speech and behavioural regulation (Westby & Cutler, 1994). Westby and Cutler (1994) also proposed a language based deficit in ADHD. Their investigation of the DSM IV ADHD criteria resulted in the claim that many of the symptoms reflect pragmatic and metacognitive skills, which are language based, rule governed behaviours. These researchers presented the argument that rule-governed behaviour frequently occurs in response to linguistic input (Zettle & Hayes, 1983). Even where others are not present individuals are expected to adhere to previously stated verbal instructions. Self-control is often exerted by recall and 'subvocal' repetition of rules.

Research has also indicated several possible links between language and attentional resources. Language is thought to mediate how humans focus attention. However, without attention it may not have been possible to acquire language. Language and attention both require frontal system activation, as does inhibition. More specific to claims of language disorder in ADHD there are widespread reports that children with ADHD are impaired on metacognitive and pragmatic tasks which are essentially language based. These include tasks that involve planning, monitoring, evaluating (Westby & Cutler, 1994). Individuals with ADHD frequently fail to listen, are unable to take turns in conversation, talk too much and interrupt.

In short these researchers reiterated the argument of Luria and Vygotsky that self-control and regulation are dependent upon internalisation of rule governed language. Importantly, these researchers reported a range of studies showing delayed language acquisition (Hartsough & Lambert, 1985; Szatmari *et al.*, 1989) and language impairment in ADHD (Cantwell *et al.*, 1979, 1981).

Further support comes from research into the cognitive features of language disorders. This research has identified a common central auditory processing disorder in both children with language impairments and children with ADHD (Riccio *et al.*, 1994). Keith and Engineer (1991) concluded that participants with ADHD were developmentally delayed in terms of auditory attention, auditory processing and receptive language. Manassis *et al.*, (2000) also concluded that children with co morbid ADHD and anxiety showed reduced auditory emotion recognition. However, this may be due to co-morbid anxiety rather than ADHD. It may therefore be that impairment of language causes the symptoms of ADHD. Alternatively, this may be further evidence of a primary cognitive impairment, such as disinhibition, that results in secondary problems of language acquisition and utilisation.

2.5.11 Evidence for Contextual Influence in ADHD: Optimal Stimulation

According to the theoretical accounts outlined in the previous sections the symptoms of ADHD are likely to be caused by a combination of pervasive biological, neurological influences that impact on cognition and behaviour. However, evidence also exists which suggests that way in which environmental influences interact with these neurological factors should not be ignored. Situation and context may have critical effects on both cognition and behaviour and also neurological function. Although ADHD may be a pervasive neurological disorder it is possible that contextual features may interact with neurological deficits to determine behaviour and performance. For example, it is argued that neurological activity might be stimulated by manipulation of factors that increase an individual's interest, motivation, effort and arousal levels. There are several theoretical accounts of ADHD that take into consideration the potential influence of context.

The Optimal Stimulation Theory was first proposed by Zentall (1975) and later refined by Zentall and Zentall (1983) and Zentall and Meyer (1987). According to the optimal stimulation theory in order to perform a task well an individual must reach their optimal

level of arousal. Problems seen in ADHD were said to occur due to understimulation and failure to reach this optimal level of arousal. This problem is particularly evident where tasks themselves are not stimulating (under activating). It was suggested that it is not that those with ADHD have inadequate resources, but that they have difficulty in reaching an activation level that facilitates mobilisation of their resources (Leung & Connolly, 1994). This in turn impacts on resource utilisation and allocation to different task demands (Carlson *et al.*, 1991; Sergeant & Scholten, 1985).

Sanders (1983) also attributed impairment in ADHD to dysfunction in effort or activation systems. Sanders identified three energetic systems. These were the arousal system that alerts sensory activity, the arousal system responsible for activation of control of motor readiness, and the system responsible for effort, as influenced by motivational factors such as knowledge of results and self regulation (Pribram & McGuiness, 1975; Sanders, 1983). Motor response problems were said to reflect underlying dysfunction in these three energetic mechanisms, particularly the arousal system responsible for activation of control of motor readiness and effort. This system was said to be strongly influenced by motivation (Sergeant, 1995, 1996; van der Meere, 1996). Activation was defined as 'readiness to respond'. According to this model, in order for a motor response to occur an optimal activation state must be reached which allows preparation to respond.

In summary, according to Sanders (1983) the behaviours that typify ADHD occur due to an underlying deficit of three energetic states, whereby resources do not reach optimal levels. This most frequently impairs activation. Lack of energetic state was also said to result in lack of effort, a view shared by Douglas (1999). The model accredits poor performance to a lack of motivation, arousal and effort. In particular it accounts for poor performance on measures requiring motor readiness.

The development of Sergeant's cognitive-energetic model occurred relatively recently (1999; 2000). It shared many assumptions with the other approaches described above.

Sergeant viewed ADHD as deficiency on three different levels. At the lowest level are the cognitive processes of encoding, central processing and response organisation. The deficit at this level was said to be in motor organisation (Sergeant & van der Meere, 1990). At the next level there are the energetic pools of arousal, activation and effort. The deficit at this level was thought to be in activation, and to a lesser degree effort. The highest level is said to consist of the executive functioning system. The deficit at this point was said to be one of inhibition and related ‘other executive functions’. This model is presented schematically in Figure 3:

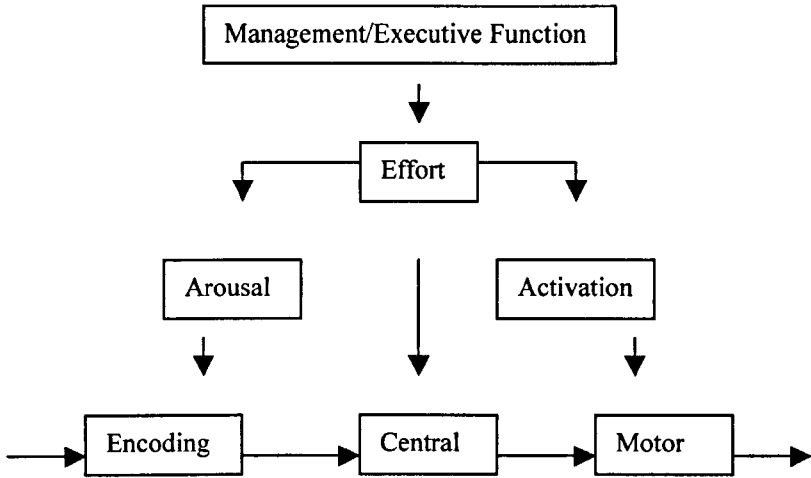


Figure 3. Sergeant’s (2000) Cognitive Energetic Model of ADHD

In summary, Sergeant (2000) attributed the deficits of ADHD to problems of motor organisation, problems of activation and effort and an executive deficit of inhibition. Disinhibition was said to be the central distinguishing feature and was said to result from failure to organise motor activity and delay responding. This lack of organisation and delay was said to arise due to deficient energetic resources that fail to activate processing mechanisms. The model proposed that any form of cognitive processing could be affected by the state factors of effort, arousal and activation and the relevant computational

mechanisms for that particular process. The model therefore accounted for problems exhibited by individuals with ADHD on a wide range of tasks, including Go-NoGo studies, Stop Signal Tasks and change tasks. Sergeant in effect combined information processing and energetic arousal accounts of ADHD. van der Meere (1996) referred to ADHD as a problem of state-regulation. A state of 'non optimal activation and effort' was said to be the core problem resulting in hyperactivity. Once again, this theory assumed that the cognitive processing mechanisms and information processing capacity are not deficient or damaged in ADHD, but that they function ineffectively due to lack of energetic input. The theory predicted that if state factors are manipulated by contextual changes to increase activation and effort then inhibitory performance can be improved. van der Meere (1996) explored this through manipulation of event rate, the assumption being that faster rates are more stimulating and thus improve performance. Findings supported this hypothesis and have been replicated in a number of studies (Chee *et al.*, 1989; Conte *et al.*, 1986; Dalby *et al.*, 1977; van der Meere *et al.*, 1992; 1995).

Fundamentally, each of these models of under stimulation imply that context is potentially very important in mediating the performance and behaviour of individuals with ADHD. They each assume that changes of the individual's level of stimulation can be achieved through careful manipulation of contextual parameters that impact on factors such as interest, arousal and motivation.

2.5.12 Optimal Stimulation: Evaluation

These cognitive energetic theories of ADHD have recently been supported by the findings of Scheres *et al.* (2001). These researchers set out to examine Quay's model. However, they concluded that participants with ADHD performed significantly worse on a Stop Signal Task in a low activation condition. Where event rates were slower participants with ADHD could not maintain the performance level they had showed in medium and high event rate conditions. Scheres *et al.* concluded that this could be due to

under arousal, under activation, poor motor preparation, sensitivity to delay or poor self-regulation. All of these were accounted for in Sanders' energetic model (1983). However, an important point to consider is that similar effects of activation level on performance were seen with participants with ODD, suggesting that a deficit of activation may not be unique to ADHD.

The predictions of three theories of hyperactivity were tested by Kuntsi *et al.* (2001). They looked for evidence of disinhibition, working memory impairment, and delay aversion (discussed in more detail later). Results indicated variability in speed of response, and generally slow and inaccurate responding for participants with ADHD. These researchers concluded that rather than providing support for the theories of working memory impairment, the delay aversion response patterns indicated a non optimal effort/ activation state as proposed by van der Meere (Kuntsi *et al.*, 2001). Kuntsi *et al.* (2001) proposed that individuals with ADHD display higher degrees of novelty seeking and stimulation seeking behaviours similar to extraverts, who have often been said to have lower levels of cortical arousal (Downey *et al.*, 1997). Furthermore they referred to observations of improved behaviour in contexts where external guidance or 'one to one' support is given. This improvement could also be attributed to the increased stimulation, effort and activation this situation can provide.

2.5.13 Evidence for Contextual Influence in ADHD: Stimulation Seeking

In another more recent account Antrop *et al.* (2000) described how failure to reach optimal stimulation (as described by Zentall, 1975) results in the stimulation seeking behaviour that characterises ADHD. Again the hypothesis was proposed that the symptoms of ADHD, such as hyperactivity and impulsivity, arise as a result of physiological under stimulation. However, once again, Antrop *et al.* described how this under stimulation can be subject to manipulation of contextual characteristics and behaviour. Individuals with ADHD are forced to compensate for low levels of cortical

arousal by engaging in stimulation seeking behaviour. In a way they self stimulate, due to 'a need to meet their high stimulation threshold' (Zentall & Zentall, 1976; 1983).

2.5.14 Stimulation Seeking: Evaluation

Antrop *et al.* highlighted findings that expressions of hyperactivity depend on environmental context. Hyperactivity has been seen to increase in conditions of low stimulation (Zentall & Zentall, 1983; Zentall & Meyer, 1987). The child with ADHD produces more activity to counteract a low level of activation (Brimer & Levine, 1983; van der Meere, 1996). This theory accounted for both Antrop *et al.*'s (2000) and Handen *et al.*'s (1998) behavioural observation study findings and a wide range of neuropsychological research. It is important to note that Antrop *et al.* suggested that stimulation seeking is an unconscious cognitive activity rather than a conscious choice. That is, individuals with ADHD are driven to seek stimulation. This contrasts sharply with the proposals of Sonuga-Barke (1994, 1995a, 1995b, 1996) and Sonuga-Barke *et al.* (1992) which are discussed in section 2.5.18, 2.5.19 and 2.5.20.

2.5.15 Evidence for Contextual Influence in ADHD: Lack of Motivation

Nigg (2001) stated that although behavioural impulsivity and poor inhibition may characterise ADHD this does not necessarily imply that disinhibition is a core deficit of the disorder. Nigg proposed that there are a number of factors that could give rise to the problems of ADHD. These include levels of arousal, activation, effort, attention, motivation and strength of impulses. More specifically, Nigg suggested that motivation is required for increased energetic arousal and activation. Nigg stressed the importance of incentive and reinforcement on motivation.

The influence of motivation was also stressed by Slusarek *et al.* (2001). These researchers also emphasised that deficits of ADHD should be regarded and investigated in terms of actual ability rather than performance on specific measures. Slusarek *et al.* criticised previous work, such as that of Logan and colleagues, as failing to distinguish between

performance and ability. A large proportion of Logan's research into ADHD has used the Stop Signal Task, but this was criticised as ignoring any relationship with affective and motivational processes.

Criticism was also aimed specifically at Barkley for failure to indicate the arousing conditions of behavioural inhibition and to clearly determine whether inhibition is global or dependent upon specific situational aspects. Slusarek *et al.* (2001) pointed out that theoretical accounts of ADHD are based primarily on observations of performance in limited settings, and as a consequence contextual factors combined with personal or dispositional factors are overlooked. These researchers again made the claim that the impact of factors such as interest, effort and motivation can significantly alter performance of participants with ADHD. They emphasised findings that given adequate motivation the performance of participants with ADHD can improve significantly (Douglas and Parry, 1994; Hinshaw, 1992).

2.5.16 Lack of Motivation; Evaluation

There is a wealth of physiological research that has suggested that motivation, triggered by reinforcement contingencies, increases activation in participants with ADHD. Such research includes studies of cardiac response and skin conductance (Iaboni *et al.*, 1997; Mezzacappa *et al.*, 1998). Once again, these studies have often indicated that motor preparation and effort is abnormally low in ADHD (Borger & van der Meere, 2000; Jennings *et al.*, 1997). This is thought to be highly dependent upon motivational factors. Slusarek *et al.* argued that the few studies that have considered motivation have failed to consider different degrees of motivation and thus different motivational states. As such it was claimed that empirical findings may have been grossly mis-interpreted. Slusarek *et al.* illustrated this point by conducting a study that manipulated levels of task incentive. Incentives were both rewards and response costs. Under conditions of lower level of incentive participants with ADHD exhibited poor inhibitory performance and executive

deficits. However, given higher levels of incentive these deficits disappeared and participants with ADHD performed as well as other groups. Slusarek *et al.* stated that ‘the actual performance can only match the capability of an individual if the motivational state is at an optimal level’. Although these researchers concluded that individuals with ADHD display lowered inhibitory control (a dispositional factor) they attributed this to motivational influence rather than an inflexible cognitive deficit.

Newman and Wallace (1993) have proposed that Quay’s (1988) model could also be used for understanding the influence of motivation on the symptoms of ADHD. These researchers supported Quay’s proposal that ADHD arises due to problems of the BIS. However, they described how it is the ability to scan the environment for cues to modify behaviour that impairs the function of the BIS. Newman and Wallace (1993) attributed ADHD to a failure of response modification. Response modification requires regular monitoring and sampling of the environment to learn new information that will inform behaviour. This was said to provide regular environmental feedback. In ADHD this was said to be impaired, thus the individual becomes stuck in dominant, prepotent responses. These researchers described how individuals are insensitive to signals, whether negative or positive, and are not easily motivated by them.

2.5.17 Evidence for Contextual Influence in ADHD: Sensitivity to Reinforcement and Incentive

Expanding Quay’s assumptions, Newman and Wallace suggested that ADHD reflects poor sensitivity to signals, failure of the BIS, and failure of the BIS to interrupt the BAS. Again, this was said to be likely to arise due to lowered neurological function and poor cortical arousal. However, support for Newman and Wallace’s (1993) proposal is inconsistent and studies investigating sensitivity to signals inconclusive (Nigg, 2001). In particular there is a wealth of research that, in contrast to Quay’s and Newman and Wallace’s claims, has documented sensitivity of participants with ADHD to contextual

factors in the form of signals of both reward and punishment. However, such research has continued to attribute core symptoms of ADHD to motivational factors.

However, unlike Barkley (1997b) and Quay (1988), researchers such as Douglas (1989), Douglas and Parry (1983; 1994) and Gorenstein and Newman (1980) have viewed problems of ADHD as over activation. The proposal was that individuals with ADHD have an overactive BAS that results in the individual being over motivated to achieve rewards. Given the correct degree of incentive this may aid performance. However, too much has been said to cause impulsive responding and over activity to signals.

Incentives can therefore enhance performance but they may also be distracting, encouraging individuals to focus on achieving rewards rather than to respond appropriately and accurately. Iabonli *et al.* (1995) reported that participants with ADHD over-responded in experimental conditions where signals were for either reward, punishment or response cost. Thus, they concluded that even where signals are negative participants with ADHD appear to be stuck in a response style that promotes over activity.

However, others have argued that negative signals promote improved performance as they are arousing but trigger avoidance mechanisms and increase focus on error making. Manassis *et al.* (2000) suggested that improved performance of participants with co-morbid anxiety and ADHD was attributable to the fact that worry has a motivating effect.

2.5.18 Delay Aversion

One of the most novel and controversial accounts of ADHD was proposed by Sonuga-Barke (1994; 1995a; 1995b; 1996; 2000) and Sonuga-Barke *et al.* (1992). This account, prompted by criticism of the predominantly cognitive approach to understanding the role of inhibition, stressed the importance of measures that look at the wider implications and psychopathological dysfunctional element of hyperactivity. Sonuga-Barke argued against the 'can't inhibit' account and proposed that impulsiveness is an adaptive response,

highly influenced by temporal information. In his earlier work Sonuga-Barke conceptualised the cognitive problems faced by those with ADHD as deviant cognitive style whereby inhibitory problems are the result of a motivationally driven, response style. This was described as the 'delay aversion theory'.

The approach focused on the individual with ADHD's motivation to avoid temporal delay or repression of responses. Impulsive behaviour was described as an attempt to reduce this delay (Sonuga-Barke *et al.*, 1992). Sonuga-Barke attributed delay aversion to 'behavioural economics' (Rachlin, 1980) where response style in a wider context is considered. This was important and directly contradicted Barkley's (1997a; 1997b) proposal that in order to be able to consider temporal information the individual must first be able to stop and think, in other words he/she must be able to inhibit. According to Barkley's account, as a result of a deficit of inhibition, individuals with ADHD cannot consistently consider such temporal information.

Of particular importance to theoretical debate was Sonuga-Barke *et al.*'s (1992) emphasis that delay aversion is a process which is distinct from impulsiveness. Impulsivity suggests cognitive dysfunction beyond the control of the individual. Alternatively delay aversion is a strategy chosen on the basis of the priority to avoid delay.

2.5.19 Delay Aversion: Evaluation

Based upon their empirical research findings Sonuga-Barke *et al.* (1992) concluded that in situations where hyperactive participants were given a choice (of smaller but immediate rewards or larger, but delayed ones) and the opportunity to influence the duration of delay, these hyperactive participants responded so as to reduce the delay involved in the task. However, where the chance to reduce overall time on the task did not exist participants with ADHD were able to make the best of the situation and attend sufficiently to perform well on a memory task. Sonuga-Barke *et al.*, like Barkley (1997a; 1997b), made the additional claim that problems of memory occur as a 'side effect' of a

primary problem. For Sonuga-Barke *et al.* (1992) the primary problem was delay aversion, for Barkley (1997a,b) it was inhibitory dysfunction.

Despite these findings there are several factors that need to be considered when examining the implications of Sonuga-Barke *et al.*'s findings. Sonuga-Barke *et al.* (1992) showed that under externally imposed time restraints hyperactive participants were able to attend to information in order to perform well on a memory test. But it should be noted how this time limit was imposed. Participants were actively encouraged by the experimenter to stay focused and to take their time to look at the information presented. This factor may account for an improvement in performance.

Theories that stress a cognitive deficit of inhibition also describe how an external locus of control can facilitate inhibitory function. In addition many behaviour management techniques involve presentation of external cues or reminders designed to promote stop, look and listen mechanisms (Posavac *et al.*, 1999). The experimenter becomes an external regulator compensating for the poor abilities of the participant. Therefore it may not be that the delay averse participant realises the pointlessness of impulsive responses, but that with external help a cognitively impaired participant is prompted to stop and is reminded of the task, and this enables them to inhibit some of their impulsive behaviour.

Sonuga-Barke *et al.*'s observations also focused largely on hyperactive behaviours in laboratory based settings and on specific empirical tasks. Schweitzer (1996) criticised this approach as being less successful in accounting for 'real world' problems of inhibition and hyperactivity. For example, real world observations made of individuals with ADHD have indicated problems suppressing behaviours such as spontaneous verbal outbursts and motor activity. These are not necessarily always in direct response to any particular stimuli, where reinforcement is expected or where the child faces a delay. In this respect it can be difficult to see how a desire to avoid delay is responsible, especially where the child is already engaging in another activity. Other theorists have pointed to the

possibility that Sonuga-Barke *et al.*'s findings may be influenced by the presence of co-morbid disorders. Kuntsi *et al.* (2001) reported that although group differences were observed on their delay aversive behaviour measure these did not remain significant when conduct problems had been taken into account. They suggest that further research is needed to examine the specificity of delay aversion to ADHD.

There is a considerable amount of overlap between Sonuga-Barke *et al.*'s observations and the approach proposed by Antrop *et al.* (2000) who also described hyperactivity and impulsiveness as a type of 'delay aversion'. However this delay aversion was viewed as behaviour driven by a deficit of arousal. The individual with ADHD was said to suffer from low levels of cortical arousal and a high stimulation threshold. To compensate they were said to behave in a stimulation seeking manner. Delay of the nature discussed by Sonuga-Barke *et al.* (1992) was essentially time without stimulation. Thus during delay Antrop *et al.*'s hypothesis suggests that the individual with ADHD was driven to seek external stimulation. The child with ADHD is seen to choose smaller and more immediate rewards as this provides more constant and quicker stimulation.

However, Antrop *et al.*'s hypothesis does not immediately appear to account for Sonuga-Barke *et al.*'s finding of ability to withhold responses where this resulted in overall delay. In response to this it is important to consider the methodological characteristics of Sonuga-Barke *et al.*'s (1992) study. Importantly the study in which hyperactive children were able to withhold responses was the first of two studies. The majority of participants took part in both studies (twenty-seven out of thirty-one). As has been noted, Antrop *et al.* (2000) proposed that hyperactivity and impulsiveness can be context dependent. Where the context is novel or interesting hyperactivity and stimulation seeking behaviours reduce. It is possible therefore that in the first of the two experiments the novelty of the context facilitated better inhibitory performance.

Similarly, Antrop *et al.* (2000) argued that it is possible that behaviour interpreted as delay aversion could reflect altered perception of time in ADHD. They raised the suggestion that participants with ADHD may overestimate the amount of time that has elapsed. A lower tolerance of delay could be a reflection of a different subjective experience of time. To test this hypothesis Antrop *et al.* (2000) asked participants to estimate the time of a waiting period. However, comparison between hyperactive and non hyperactive groups showed no significant differences between estimates of the delay period. This concept needs further investigation before conclusions can be drawn about timing deficits in ADHD.

2.5.20 Dual Pathways

Such criticisms of the delay aversion theory cannot be applied to Sonuga-Barke's (1995, 2002) Dual Pathways Model. In this more recent model Sonuga-Barke concluded that both a neuro-cognitive disorder of regulation, i.e. inhibition, and a disorder of motivational style are pathways to the different forms of ADHD. This model distinguished between such processes in terms of separate processing pathways and suggested how each of these pathways can account for the range of individual differences seen in the performance and behaviours of individuals with ADHD. Sonuga-Barke argued that dysregulation of action and thought, created by a deficit of inhibition, result from dysfunction of the 'meso-cortical' pathway, associated with the branch of the dopamine system that projects into cortical control centres (e.g. prefrontal cortex) (Sonuga-Barke, 2002, pp. 32-33). In contrast a separate pathway associated with a different part of the dopamine system was said to be responsible for the delay aversion motivational style. It was suggested that a 'shortened delay of reward gradient' can be attributed to function of a 'meso-limbic' pathway linked with the dopamine branch associated with the reward circuits e.g. nucleus accumbens (Sonuga-Barke, 2002, pp.32-33).

There is considerable neurological support for dysfunction of both cortical and limbic systems. Despite variation in the names given to these systems, their hypothesised effect on function remains consistent. For example, Viggiano et al. (2002) hypothesised that there is a nigrostriatal dopamine system responsible for control of motor function, while a mesocorticolimbic dopamine system is implicated in motivation, response to reward and sustained attention.

The dual pathways model suggested that in addition to individuals for whom the primary effects on cognition result in a lack of inhibition resulting from meso-cortical dopamine system dysfunction, there are those who experience effects of the delay aversion motivational style. The engagement in task irrelevant behaviours associated with stimulation seeking was thought to result in a reduction in the total amount of time spent engaging in the cognitive activities which eventually lead to the opportunity to develop higher order processing skills (Sonuga-Barke, 2002). In contrast to the core inhibitory deficit theories, posited by researchers such as Barkley (1995, 1997a, 1997b), this account proposed that lack of inhibition does not solely and directly give rise to deficits in other executive functions. Instead the effects of a lack of inhibition and the impact of delay aversion can both reduce the amount of time spent developing these executive skills. Differences in environmental experiences will thus contribute to development of executive skill. This may account for the wide variation in executive skill and ability exhibited by those with ADHD.

Sonuga-Barke was not the first researcher to hypothesise a model of dual pathways in an attempt to account for the problems observed in ADHD. Rapport *et al.* (1999) published a paper discussing parallel but correlated developmental pathways in attention deficit and conduct disorder. This work was largely an expansion of the dual pathways proposed by Fergusson *et al.* (1993, 1995) in an attempt to account for early behaviour and IQ and relationship to later scholastic achievement. Although the focus was on the relationship to

later academic achievement these researchers also distinguished between behavioural and cognitive pathways. Deficits in the cognitive pathway result in attentional problems, whereas deficits in the behavioural pathway result in conduct problems. Deficits in both pathways were attributed to ADHD. In this respect overlap between ADHD and CD, ODD and other externalising disorders can be attributed to shared problems of the behavioural pathway. Structural equation modelling supported claims that ADHD affects both behavioural and cognitive mediating variables.

Indeed, further, indirect, support for the dual pathway model comes through investigation of the claims of Quay (1988). In effect Quay's model was one of dual pathways. Quay described how both the BIS and the BAS are reliant on dopaminergic activity.

Importantly Quay attributed activation of the BAS to dopaminergic input to a mesolimbic system and made the claim that when input is high (motivation is increased) the individual is more sensitive to signals of reward.

2.5.21 The Model of Johansen *et al.* (2002)

The model of ADHD presented by Johansen *et al.* (2002) considered the role and relationship between responses to different types of reinforcement to be an important feature of the disorder. The model was developed to account for empirical findings of differential patterns of response to reinforcement in children with ADHD. It is essentially a dual pathways model of ADHD and corresponds to that presented by Sonuga-Barke (2002). However this dual pathways model focused primarily on dysfunction of reinforcement and extinction processes.

The model proposed by Johansen *et al* (2002) is presented in Figure 4.

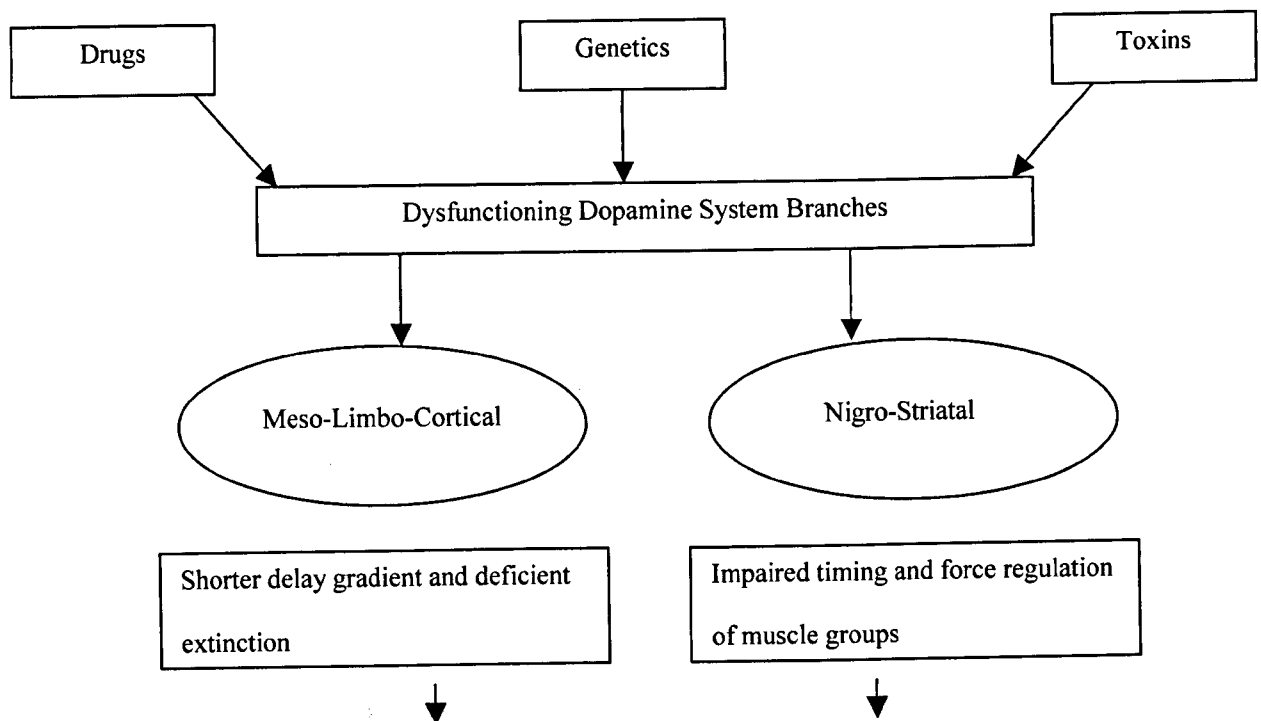


Figure 4. Johansen *et al.*'s (2002) Dual Pathways Model

According to this model in order for reinforcement to take place increased dopamine is required. This was said to occur with strong, immediate, salient, or novel stimuli. Johansen *et al.* hypothesised that altered sensitivity to reinforcement and faster erosion of the effect of the reinforcer affect ability to learn stimulus response associations. Altered reinforcement mechanisms therefore have a direct impact on language and rule acquisition, which are acquired at a much slower rate, resulting in developmental delay or maturational lag. Johansen *et al.*'s model can account for context dependent hyperactivity and inhibitory control.

2.6 Non Medical Interventions for ADHD: Support for the Potential Impact of Context on Behaviour and Performance.

In addition to the medical interventions for ADHD there are a wide range of treatment options currently being explored that aim to address the underlying difficulties of cognition and the behaviours associated with poor executive function, inattention and

hyperactivity/impulsivity. These options are diverse and complex and will differ greatly according to the specific needs and diagnosis of the individual and any co-occurring conditions. However, the common underlying assumption made by these approaches is that by carefully changing and structuring contextual parameters the behaviour of children with ADHD can be modified. The following section briefly reviews some of the most common treatment options and their assumptions about the ways in which context might impact on behaviour and cognition. It is important to note that in many cases these summaries are considerably simplified.

2.6.1 Strategies directed at the Management of Behaviour

There are many strategies employed to aid the management of both behaviour and cognition. Strategies directed at addressing undesirable or inappropriate behaviours include: *token economy systems*, to promote establishment of desired behaviours where tokens are accumulated and later exchanged for desired rewards; *time out*, to promote extinction of undesirable behaviour through minimising reinforcement to that behaviour commonly by removal of the individual or sometimes the reinforcer and *extinction*, to promote cessation of unacceptable behaviour often using reward systems of reinforcement contingencies where acceptable behaviour is exhibited. They also include: *contingency contracts*, to promote motivation to achieve desired behaviour through establishment of 'contract; for acceptable behaviour (this often involves reward or response cost system); *positive reinforcement*, to promote desirable behaviours using rewards that can be material e.g. sweets or money, social, e.g. praise, or desired activities, e.g. a trip to the cinema; *modelling*, to promote learning of new behaviours through imitation; *prompting*, to promote appropriate responses to specific instructions through cueing; and *punishment*, to promote immediate cessation of undesirable behaviour using unpleasant consequences or withdrawal of a desirable item, activity or other stimulus. These strategies may vary greatly in the ways in which they are applied, however they share the common assumption that the contexts can be modified to place greater an

emphasis on the desired behaviour. For many of these strategies this is achieved by offering reinforcement following the target behaviour.

2.6.2 Strategies directed at the Management of Cognition and Emotion

Strategies focusing on contextual modifications have also been developed to specifically address the cognitive and emotional difficulties associated with ADHD. These include approaches such as *cognitive retraining*, *shaping* and *behaviour modification* which aim to promote inner control of thoughts and actions and to develop controlled 'inner speech' mostly through modelling and repetition of instructions, first externally and then internally. These approaches aim to address problems of self regulation and assume that with careful structuring of external narratives, internal cognitions can be redirected to become more appropriate. Framing and careful structuring of the way in which information is processed is also the focus of *assertiveness training* which aims to promote the individual's ability to express thoughts and emotions in more socially acceptable manner and to promote social interaction. Role play and one to one training are just two of the approaches taken to this framing or structuring so that cognitions become contextualised.

Other techniques exist to address the way in which settings and encounters are perceived and responded to by the individual with ADHD. For example, *relaxation training* aims to promote calmness using specific exercises and breathing techniques; *systematic desensitisation* aims to promote elimination of fear or anxiety through exposure to fear stimulus in small amounts accompanied with relaxation techniques; and *mood management training* aims to promote control of emotion and emotional expression through exercise, positive activity, positive cognition, counselling, assistance and distraction.

Similarly therapeutic interventions are frequently promoted to address and reshape perceptions, cognitions and emotions. Once again these approaches seem to share the

assumption that the way in which cognitions and emotions are contextualised can have an important impact on behaviour. Train (1998) summarised the myriad of approaches as falling into one of the following categories: counselling; psychoanalysis; Gestalt therapy; family therapy; rational emotive therapy; interpersonal Cognitive Problem Solving; stress inoculation training; self instructional training; transactional analysis; and finally, psychosynthesis.

2.6.3 Time and Educational Management

As discussed in sections 2.1 to 2.7, one of the most significant problems facing individuals with ADHD is their apparent lack of self regulation. Many strategies exist to address difficulties that arise from this impairment which interrupts daily functioning across home and educational settings. The role of context is critical in these approaches which focus on the provision of some form of external prompt or guide for behaviour. For example, time management strategies aim to promote organisation, planning, preparation etc, through training in time awareness and time monitoring. These approaches frequently involve cueing and prompts, often mechanical, e.g alarm, stopwatch. There is also an extensive list of specific educational management strategies aimed at promoting inclusion, learning and academic achievement. These approaches focus on a range of environmental manipulations, such as classroom modification, specialist teacher input and teaching strategies, strict routine and timetables, and an amalgamation of several of the behaviour management techniques listed here. This is highly dependent on dedicated teacher input and the consistency and frequency of reinforcement and carefully controlled rules that are highly visible and frequently reminded. In essence, each of these approaches rely on some very specific contextual manipulations, necessarily implicating that the behaviours and performance of individuals with ADHD can indeed be affected by manipulations of context. However, questions remain concerning the success of these non medical interventions and thus this evidence in support of the effects of context must be treated with caution.

2.7 Cognition and Context: Anecdotal Evidence

Despite the overwhelming empirical support for pervasive executive, and in particular inhibitory, deficits in ADHD and in line with the theories of ADHD which suggest that context has an important role to play in mediating the interaction between cognitive deficits and performance and behaviour, anecdotal evidence has emerged that raises questions over the primacy and stability of these deficits in differing contexts. To be more specific, there is a small amount of anecdotal evidence that suggests there are certain situations in which the observed problems of inattention, hyperactivity and poor inhibition can be somewhat reduced or temporarily overcome. Several authors, including Barkley (1995), Nash (1994), and Serfontein (1990), have noted that children with ADHD often show particular interest and considerable success on a particular activity that requires successful execution of several inhibitory skills. This activity is computer, console or video game playing (hereafter referred to simply as computer games).

When playing computer games children with ADHD are often observed sustaining attention for much greater periods of time than is evident in the empirical tasks noted earlier. Barkley suggested that children with ADHD show few attentional deficits when playing computer games as a consequence of the nature of the rewards that tend to be immediate and continuous throughout computer games. Others (e.g. Serfontein, 1990) have accounted for the child with ADHD's concentration on these games by referring to their motivational aspects. Nash (1994) pointed to high levels of stimulation as a contributory factor.

Of importance to this thesis is the nature of these observations and their implications for understanding the role of context in the cognitive performance of children with a constitutional disorder with core neurological deficits.

It is not immediately evident how core deficit theories such as that of Barkley (1997) can account for instances of improved behaviour and performance in particular settings. According to the core deficit approach ADHD arises due to persistent problems of disinhibition and the secondary effects this has on a series of executive functions. If children with ADHD have a such a central cognitive deficit it seems likely that they should perform poorly on all activities which require them to concentrate, ignore distractions, forward plan, select appropriate responses and avoid impulsive responses. However, theories of ADHD that suggest that these core deficits might be subject to contextual effects appear to offer a potential solution to understanding this phenomenon. In particular, this anecdotal evidence may be accounted for by models of ADHD that focus on the contextual effects of stimulation and motivation on the performance of individuals with ADHD. The anecdotal evidence therefore suggests that these alternative accounts of ADHD merit further consideration and examination. Despite these anecdotal reports there has been little investigation into these contextual influences on performance. This was therefore proposed as the aim of this thesis.

Chapter 3

Methodology

Despite the strong empirical support for an executive processes deficit in ADHD, the anecdotal evidence presented suggests there are certain situations in which problems of self-regulation, organisation, planning and attention are somewhat reduced or temporarily overcome. This anecdotal evidence, if substantiated, may indicate a need for greater focus on contextual effects on the performance of individuals with ADHD. It is often observed that children with ADHD can pay attention, focus, sit still and concentrate, organise and apply strategic problem solving skills when doing something of extreme interest to them. Such reports raise questions about the research methods employed to investigate the cognitive competence of individuals with ADHD.

In order to study the effects of context on the performance and behaviour of children with ADHD there are several methodological issues that need to be addressed. First it is necessary to consider some of the criticisms that have been directed at research in this area from an epistemological perspective. Concerns have been raised on several levels and are outlined in this chapter. Sections 3.1 and 3.2 therefore offer a critique of the research methods and tools used to assess cognitive processes, particularly executive function, in ADHD.

Second, it is important to consider the anecdotal evidence concerning the performance of children with ADHD on computer games in terms of these methodological issues and concerns. Section 3.3 evaluates the potential use of computers as an ecologically valid method for assessing the performance and behaviour of children with ADHD.

Third, it is also important to address concerns connected with participant selection. There are several key factors that might confound the performance of children with ADHD on

measures of executive function. In particular, IQ and the presence of co-morbid disorder may significantly impact on performance. These concerns are outlined in section 3.4.

The final section of this chapter takes into consideration these issues and concerns and concludes by proposing that a methodology that focuses on the validity of differing contexts be adopted for the study of the performance of children with ADHD. This section outlines the ensuing research proposal and following a review of the available evidence it is proposed that the Conner's CPT be used as a measure of executive function, and that participants' IQ, experience and co-morbid disorders be carefully considered in the experimental design.

3.1 Epistemological Concerns: Measures of EF and ADHD

3.1.1 Identifying Individual Processes

Successful performance on EF tasks, such as those described in section 2.3.2, requires skills such as attentional flexibility, proficiency in skills such as attribute identification, utilisation of verbal feedback and categorisation. The tasks rely heavily on working memory, inhibition and selective attention (Bond & Buchtel, 1984; Dehaene & Changeux, 1991; Ozonoff, 1995b; Perrine, 1993; van der Does & van der Bosch, 1992). It is not always clear which skills are more influential on performance. While some argue that processes such as working memory and attention are themselves executive functions, others believe they are inter-related but distinct processes. Similarly, processes such as spatial and verbal processing ability have commonly been referred to as additional, non-executive, functions (Kelly, 2000).

Despite the complexity of processing required for successful performance on EF measures Ozonoff (1997) highlighted the tendency of research to treat EF as a single construct. Pineda *et al.* (1999) also drew attention to the trend of attributing failure on such tests to a single form of deficient processing ability. As a result many individual

processes are ignored and the complexity and importance of the relationship between processes has not been systematically examined.

The tests described in Chapter 2 are just a few examples of the sorts of tasks used as measures of the construct termed ‘executive function’ that require competence in several skills for success. Despite the variety of tests of EF, there is considerable need for greater specificity in terms of the cognitive functions they aim to assess (Kelly, 2000). This is, in part, probably due to the lack of a universally agreed definition of EF. It is particularly evident that many of these measures, often used to examine the ability to plan and execute goal directed behaviour, rely on the effective integration of several key processes. These individual processes are rarely identified.

As a result researchers such as Culbertson *et al.* (1998) have stressed the need for a new battery of EF tests. New tests that attempt to identify specific executive processes rather than a general executive ability may enable more detailed examination of the specific cognitive profiles. If achieved this would aid clarification of the cognitive abilities of individuals with disorders such as ADHD and would facilitate study of processes, such as inhibition, in isolation.

3.1.2 Multifaceted Processes

Another criticism of EF research is that the majority of studies fail to acknowledge that there are differences in the types of inhibition, memory and attention described. Different forms of these abilities affect behaviour in different ways (Tannock, 1998). It is important that research clearly identifies the forms it aims to study.

Again, these criticisms suggest that due to the multifaceted nature of EF, any measures employed should facilitate examination and consideration not only of overall success but also of the individual processes involved, in addition to the nature of task presentation. Kelly (2000) suggests that this approach may improve the specificity of EF measures.

3.1.3 Performance Compared to Competence

Further criticisms have been levelled at the fact that EF tasks assess performance on problem solving tasks rather than the actual processes involved. As such EF assessment is primarily quantitative as opposed to qualitative (Meltzer, 1994). Research findings have therefore given an index of performance in very constrained settings. EF tests do not currently allow examination of the interrelationship between cognitive processes and external influencing factors such as personality, social factors and individual motivation (Kelly, 2000). As such an individual's actual competence may be misrepresented. In order to provide a better estimate of competence measures need to become more 'dynamic' (Feuerstein et al., 1979). Kelly (2000) refers to 'dynamic' measures as those that recognise the influence of social context, the potential for individuals to learn more effective strategies under guidance and the importance of EF measures for promoting the development of intervention techniques.

3.2 Measures of Inhibition: Evaluation

Despite the existence of more specific measures designed to facilitate focused study of inhibition these tools have also been criticised on several levels.

Sonuga-Barke (1996) suggested that tests of inhibition actually focus more on impulsiveness and fail to promote understanding of the wider implications of psychopathological behaviour. This criticism points to the need for integrated and applied research. Sonuga-Barke also suggested that traditional measures can be vulnerable to the effects of response style. For many tests impulsive responding can often result in a shorter testing session. It is possible that participants respond impulsively because they want to end the session sooner. Therefore what is needed is a test where impulsive responses do not reduce the overall length of a testing session.

Sonuga-Barke (1996) also stressed the importance of distinguishing between presentation time and time spent on-task (Ceci & Tishman, 1984; Dalby *et al.*, 1977). Clearly

participants do not always use all the time given to them to focus on the task. This may be a useful tool in identifying hyperactive and impulsive participants.

3.2.1 The Stop Signal, the Change Signal Task and the Stroop Test.

Essentially these tasks have all been criticised as being irrelevant, boring and too complex to make any sense or to be in any way appealing to young children, particularly those with attentional problems. Performance on some traditional manipulations of the Stroop Test can be confounded by verbal and reading ability and children are required to engage in counterfactual reasoning. In general these tasks require one repetitive movement in response to stimuli, and as such can become monotonous.

3.2.2 The Anti Saccade Task

In order to process the information presented during the test the individual must rely on quite complex and counterintuitive instructions stored in working memory (Roberts *et al.* 1994). The participant must withhold a prepotent, reflexive response, and to shift attention elsewhere. As with the Stop Signal Task the distinction between errors of attention and inhibitory control is unclear. It is possible that failure to attend could be interpreted as both failure to inhibit, if the participant responds by chance at the wrong time, and successful inhibition, if the participant was not attending and therefore not responding.

3.2.3 The Detour Reaching Box Test

This test places a large demand on memory and in this respect the test is not just a measure of inhibitory control. The test is quite complex and it consists of three stages: the child must look at the light, remember to inhibit a reaching response and then decide which switch to activate. Failure could reflect the test's complexity and demand on memory rather than difficulty in inhibiting a prepotent response.

3.2.4 Luria's Hand Game

This task does not rely heavily on verbal ability or memory and can be made into a game. However, it is necessary to make sure that the child understands that the experimenter wants him/her to produce an opposite action in the conflict condition. For some children producing a shape opposite to the experimenter could be quite intimidating and unusual.

3.2.5 Heart Rate Change

Several methodological criticisms can be made of Jennings *et al.*'s (1997) study. The task relied on fine motor skills and visual ability, but of major concern is the level of motivation intrinsic in the task and its subsequent impact on attention. It is debatable whether the task was relevant to the children being tested. It may be that participants took longer to respond appropriately because they were not motivated to fully attend to the task. Also of concern is the use of heart rate as an index of inhibition. Heart rate may be affected by cognitive mechanisms, alternatively cognitive mechanisms may be affected by heart rate.

3.2.6 A Desire for Immediate Reward

Schweitzer and Sulzer-Azaroff (1988) considered impulsivity to be a significant problem of ADHD. These researchers criticised empirical work in this area for failing to look at the 'real world' dysfunctional nature of ADHD. They argued that problems, such as poor inhibition, need to be viewed in context. These researchers observed the behaviours of participants with ADHD on a task involving a choice between smaller rewards, received immediately, or larger but delayed rewards. Participants with ADHD consistently chose to receive immediate but smaller rewards. Schweitzer and Sulzer-Azaroff (1988) reported that participants with ADHD acted impulsively and displayed apparent disregard for the size of a reward. These findings were said to highlight the dysfunctional nature of a lack of impulse control faced by hyperactive individuals.

This methodology was later employed by Sonuga-Barke *et al.* (1992). Sonuga-Barke *et al.* presented hyperactive children with a choice of responses. Children could choose to respond immediately and receive smaller rewards, or to delay their response in order to receive a larger reward. Results showed a clear preference for immediate responding where delay was short but rewards small. However, in an earlier study where immediate responding also resulted in a longer post reward delay these children more frequently chose to respond to the delayed larger reward.

In a second experiment Sonuga-Barke *et al.* (1992) emphasised the importance of the hyperactive child's delay averse response style on expression of inhibition. When given a self imposed time limit on a memory task hyperactive participants spent less time attending to stimuli. This resulted in greater error making. This result in isolation could be attributed to impulsiveness beyond the control of the participant. However, Sonuga-Barke *et al.* also presented a new version of this task under an externally imposed time limit. For this task hyperactive participants performed as well as controls.

Sonuga-Barke *et al.* (1992) concluded that hyperactive children responded in a style that showed 'indifference' to rewards, and that resulted in less overall delay. Hyperactive children were able to withhold responses only where this resulted in less delay over the testing session. Impulsive behaviours and responses were observed more frequently where delay was longer or reinforcement delayed. The results of Sonuga-Barke *et al.*'s (1992) study were consistent with those of Schweitzer and Sulzer-Azaroff (1988) but were interpreted as a reflection of a deviant response style labelled 'delay aversion' rather than the result of a cognitive deficit of impulsivity.

However, Schweitzer (1996) claimed that the rewards used in these tasks may have been inappropriate. More salient and relevant rewards might have motivated and encouraged the participant more. It may not have been that participants with ADHD disregarded rewards but that the rewards were insignificant or meaningless and, as such, they did not

motivate the participants sufficiently for them to be able to delay their responses. The sensitivity to size of rewards needs to be carefully considered, as it may be that impulsivity results from a reduced sensitivity to reward.

In summary, there are several important criticisms aimed at these methods used to evaluate the performance of children with ADHD. These include: their reliance on working memory and selective attention; being irrelevant, boring and too complex to make any sense or to be in any way appealing to young children, particularly those with attentional problems; the likelihood of performance being confounded by verbal and reading ability; their complexity and frequent need to engage in counterfactual reasoning; their repetitive nature and monotony, their use of constrained settings, a failure to allow examination of the interrelationship between cognitive processes and external influencing factors such as personality, social factors and individual motivation; the potential for misrepresentation of competence; a failure to promote understanding of the wider implications of psychopathological behaviour, the need for more integrated and applied research and vulnerability to the effects of response style; the use of tasks that are not intrinsically motivating; the use of inappropriate, insignificant or meaningless rewards and a failure to consider the size of rewards or sensitivity to rewards.

3.3 Computer Game Playing: An Ecologically Valid Measure of Performance?

Despite the anecdotal reports of improved behaviour, attention, success and performance of children with ADHD while playing computer games and the implication that this has for contextual effects in ADHD, there has been little investigation into the possible influences of such games on performance. There has been no systematic research into children with ADHD's engagement and performance on computer games. If children with ADHD can attend and concentrate in certain situations but not others, this raises

important questions concerning the role of context, the nature of the disorder and of the interpretation of research findings in less ecologically valid settings.

It is important to assess the extent to which computer games might be useful as a research tool, and specifically, whether they might offer an approach that overcomes some of the criticisms aimed at the more traditional methodologies outlined in the preceeding sections. The answer to these questions is of significance both theoretically in terms of explanations of cognition in context and of ADHD, practically in terms of advice for parents and professionals, particularly in identifying circumstances in which poor performance may be overcome, and methodologically in terms of approaches taken in experimental design and interpretation. Given the potential significance of these anecdotal reports, it seemed crucial that research in this area was carried out.

There is an extensive body of research that examines the motivational and fun components of computer games, the computer game playing setting, features of computer games and the use of computer games in research, some of which is reviewed in the following subsections. However, despite the wealth of empirical research in this field there is, as yet, no systematic research that has been conducted that examines the interaction, abilities and behaviour of children with ADHD while playing computer games. For this reason it was only possible to review research conducted with typically developing populations in order to examine the potentially influential features of computer games on the performance of children with ADHD and the role of context.

3.3.1 Computer Games: Fun and Motivation

In acknowledgement of the potential importance of motivation Amory *et al.* (1999) assessed the different types of games available and attempted to identify those types that appeared to be the most interesting and motivating. Computer games appear to heighten the motivation of children through their stunning and compelling graphics, sounds and story lines and stimulation of the child's curiosity (Amory *et al.*, 1999; Thomas &

Macredie, 1994). Elements of novelty and complexity have also been suggested as contributory factors (Amory *et al.*, 1999; Malone, 1984; Malone & Lepper, 1987; Rivers, 1990). Amory *et al.* (1999) reported that students preferred adventure games more than any others. This may be because they contain elements of fantasy, a feature said to make games intrinsically motivating (Reiber, 1996).

Malone (1981) conducted several studies that aimed to examine the elements of computer games that make them popular and attractive to children. The factor reported to be most important in determining a game's popularity was whether the game had a clear, salient and visually satisfying goal that could be achieved. This may be one of the important features of computer games that impacts on the inhibitory performance of children with ADHD.

The elements of challenge, fantasy and curiosity found in computer games were also identified by Malone (1981) as contributing to the player's enjoyment. The element of challenge was said to contribute to the explanation for why these games are not only fun, but also motivating. For a game to have an element of challenge it was said to require a goal where the outcome is uncertain. The best goals were those which were personally meaningful. Malone observed that the most meaningful goals were those which were practical or contained an element of fantasy, rather than goals which were dependent upon skill, such as solving maths puzzles. Malone described how the element of challenge and thus motivation is lost if a goal is either certainly going to be reached or certainly not going to be reached. One way Malone proposed for ensuring that players of different abilities are presented with uncertainty is to incorporate varying levels of difficulty or multiple goal levels in the same environment (for example faster times in which to complete a level or higher scores to obtain within a level).

Malone (1981) made the point that goals challenge the player's self esteem. Challenging activities, when achieved, boost self esteem and vice versa. Failure and loss of self

esteem can reduce motivation. Game manufacturers seek to overcome this problem by including a whole spectrum of difficulty levels and by making sure that feedback given when success is not achieved is not discouraging.

The element of fantasy identified by Malone (1981) was divided into two types: intrinsic and extrinsic. Malone described how games with intrinsic fantasy are more 'fun'. These games are often more relevant to real world experience and real world goals. As such, these games are arguably more 'realistic' and relevant to young children. The child may experience improved performance on games with intrinsic fantasy as they can relate more accurately to the game environment and can use experience of the real world in order to guide interactions within the game environment. Malone (1981) described how these fantasy games allow children to use metaphors and analogies that help them to apply old knowledge to understanding new things. In addition, Malone (1981) claimed that games with intrinsic fantasy tend to be very visually and aurally stimulating. The imagery involved with these games can aid recall of the game's objectives, thus promoting better performance.

The element of curiosity identified by Malone (1981) was used to refer to game environments that are neither too complicated nor too simple and which are in some way novel or surprising. One way of sustaining curiosity is to provide a sequence of increasingly difficult tasks, adding new complications and surprises, but making sure that the goals are still within the player's grasp (Malone, 1981). Another way to sustain curiosity is to add features that stimulate sensory curiosity, such as frequently changing light, sound, audio and visual effects.

In addition, the rewards for achieving goals on computer games are frequently immediate. In contrast rewards for achieving everyday goals are often delayed and long term. This is an important consideration bearing in mind claims that children with ADHD have significant problems in delaying gratification and in understanding long term goals.

Reinforcement needs to be immediate for children with ADHD in order for it to have any effect (Barkley, 1990).

There are several additional features of computer games that have been identified by Ju and Wagner (1997) as contributing to the challenge and enjoyment of computer games. These include a game's narrative, its richness, plot, speed, role play, graphics and user interface. The key factors listed as those that make games challenging were, the tasks to be completed (goals) and the level of complexity and difficulty. The key factors listed as those that make games unattractive were, poor interface, poor graphics and sound, poor control and tasks which were either too easy or too difficult (Ju & Wagner, 1997).

3.3.2 The Computer Game Playing Setting

There are several aspects of the game playing setting that could give rise to improved behaviour and inhibitory control in children with ADHD. The computer game playing setting is a more naturalistic setting than those in which empirical tests are usually conducted. By definition, if the setting is more naturalistic then it is likely that the child will have encountered this type of situation in everyday life, for example, at home, at school or at a friend's house. In contrast more empirical laboratory based examinations of the child's abilities are often unfamiliar and a little more unusual for the child, thus it is possible that participants will be more uncomfortable and may be distracted by task irrelevant interference from feelings such as stress and anxiety.

Due to its familiarity the naturalistic setting is also likely to be an environment in which the child's understanding is more concrete than abstract. This can be important for young children, making the situation more comprehensive (Chandler & Hala, 1994). Chandler and Hala (1994), when studying theory of mind understanding in young children, also stressed the importance of making the task relevant to the child. There is a strong argument that computer game playing settings are also far more relevant for children than laboratory based tasks (Houghton, 2002).

The computer games setting may also be more exciting and stimulating as it requires direct personal involvement, where the child controls the action. There is also likely to be more stimulation in terms of visual and auditory stimuli. The speed of information presentation is also likely to be faster than for tasks used in laboratory settings. Zentall *et al.* (1985) believe that increased stimulation in terms of colours and shapes, can reduce hyperactivity levels and increase attention and performance. Zentall and Meyer (1987) also suggest that by varying the speed and form of presentation of tasks, for example by asking the child to do passive tasks, but then asking them to do more active tasks before returning to the passive tasks, performance can be optimised. All of these factors may contribute to make the naturalistic setting of computer game playing more exciting and motivating for the child.

3.3.3 Computer Games: Some Research Findings

Despite a wealth of research that has discussed negative impact of computer games, such as increased aggression and violence and the lack of social activity which may be associated with computer game playing (Subrahmanyam *et al.*, 2000), there are relatively few studies that have looked at some of the more positive effects. These suggest why computer games help to promote good inhibitory performance. Greenfield (1984; 1987) for example, found that computer games promoted the development of hand eye co-ordination, parallel and serial processing and creative thinking. Gagnon (1985), McClurg (1992), and Yuji (1996) all found that playing computer games improved spatial visualisation. Yuji (1996) highlighted the fact that computer games can tap such skills and may even improve them if played often.

More specifically, Lee and White (1990) and later Shewokis (1997) found that problems of contextual interference, which Barkley (1997b) described as a form of inhibitory control deficient in ADHD, can be reduced and even eradicated by asking participants to play computer games. Shewokis (1997) reiterated the suggestion, presented by Lee and

White (1990), that contextual interference is not found when using computer games as tasks because of the increased motivation and thus cognitive effort the games produce. Motivation appears to be a key feature identified by several other researchers (Hollingsworth & Woodward, 1993; Serfontein, 1990).

3.3.4 Features of Computer Games

Thus the question arises what is it about computer game playing that may improve the child with ADHD's inhibitory abilities and performance? There may be specific attributes of computer games that give rise to observed improvements in inhibitory function.

Computer games present information visually. This may be especially important for children with ADHD who appear to require constant prompting about task requirements and demands (Barkley, 1990). By presenting the child with a visual task they have a constant visual reminder of the task in hand. Several researchers have stressed the importance of the element of visualisation in problem solving and in gathering information from the world in order to guide behaviour, (Amory *et al.*, 1999; Reiber, 1995). The visual characteristics of computer games may therefore be extremely valuable in helping children to gather information, learn and achieve success.

When playing computer games the instructions for the task are also usually very salient. This may overcome problems of the children forgetting or misunderstanding what is being asked of them. This may mean that the children do not need to try to guess what they are being asked to do and the goal of the task may be clearer.

In computer games sensory stimuli are used for decoration, reward, to enhance fantasy and as graphic representations, which are often said to be more effective than words or numbers. These sensory stimuli can help the player to construct mental maps and visual images in order to recall elements of the game. These sensory stimuli may aid recall.

These sensory stimuli can often replace the need for information to be presented in a written format and can act as prompts, reinforcers or cues. It is often the case that tasks

reliant on verbal and reading ability present problems to young children, and children with ADHD. When tested with tasks that do not require good verbal or reading skills, children sometimes exhibit cognitive skills which were previously unobserved (e.g Bartsch & Wellman, 1989).

The acquisition of problem solving skills and increased memory retention are two of the benefits of playing adventure games identified by Ju and Wagner (1997). Other researchers have also claimed that the way in which computer games present information can aid memory (Oz & White, 1993). Different presentation formats can affect retention rates: with 20 per cent of information retained when information is presented auditorally; 40 per cent retained when it is presented visually and auditorally; and 75 per cent retained when presented visually and auditorally with active participation (Oz & White, 1993).

Computer games often require active motor responding. Zentall and Meyer (1987) suggested that the more active and motoric the task the more able the child with ADHD is to channel their behaviours and responses. Barkley (1990) highlighted the importance of short bursts of demanding material followed by immediate feedback and reinforcement. Barkley also hypothesised that by asking children with ADHD to do short periods of physical activity their mental abilities will be improved. Importantly, computer games tend to increase gradually in difficulty, speed and stimulation, and often require short bursts of increased motor activity followed by a more passive activity. A vast number of games also provide immediate feedback and are often presented in relatively short stages.

3.3.5 The Use of Computer Games in Research: A Critical View

Despite all of the evidence presented in the previous section, Donchin (1995) took a different view of the use of computer games in research. Donchin expressed the view that computer games are only a useful research tool if the researcher can exercise control over a game's parameters, thus allowing good, detailed measures of specific skills which the researcher can control and manipulate. Interestingly, Donchin (1995) stated that there is

nothing ‘particularly special about the use of video games’, they are just another research tool. However, in opposition to Donchin’s viewpoint it is suggested that by restricting the game in this way it becomes another lab based measure and potentially important features, such as the elements of fun, and motivation (the elements which make the task a game) are lost. Thus by strictly controlling computer games the researcher may risk excluding important contributory factors that may occur in more naturalistic settings. These features may significantly affect the participant’s ability to display competence rather than task limited performance and behaviour. It seems, therefore, that there is a balance to be reached here concerning the costs and benefits associated with control versus those concerned with ecological validity that must be carefully considered.

3.4 Concerns Associated with Participant Selection

3.4.1 Issues Concerning Participants

Findings using EF measures have also been viewed as contentious for additional reasons such as small sample sizes, inconsistent participant selection criteria with lack of differentiation between ADHD subtypes, and failure to account for ‘medication status’ during testing (Houghton *et al.*, 1999). IQ and language ability are also likely to be confounded with performance and yet have often been ignored (Denckla, 1994).

Another important criticism has been raised by Hughes (1998). Hughes pointed out the lack of suitable executive functioning tasks for use with young children. She acknowledged that the majority of existing tests of executive function were originally designed for adults. This occurred as a result of the view that prefrontal functions, including executive abilities, do not develop fully until adulthood. However, Hughes suggested that there is evidence that executive function develops in early childhood (Welsh & Pennington, 1988).

Subsequently Hughes (1998) developed six executive functioning tasks suitable for use with preschool children (two of working memory, two of inhibitory control and two of

attentional flexibility). These tests were modified from standard tasks used for adults and from animal tests of prefrontal function. Hughes' approach might be criticised however, as it is possible that executive functions are not all prefrontal functions. In addition her tasks involved a considerable memory load and relied on good verbal ability.

3.4.2 Confounds

There are several limitations concerned more specifically with the use of EF measures to elucidate understanding of ADHD. Performance on EF measures can be influenced by many factors, including a participant's linguistic ability, culture, age, education, socio-economic status, sex, IQ and so on (Pineda *et al.*, 1999). Much empirical work has not identified or controlled for the potential confounding effect of many of these factors and those studies that have attempted to do this have produced contradictory results. For example, results using the MFFT have shown that individuals with ADHD perform poorly on measures of inhibition. However, this performance has been highly correlated with IQ score (Milich & Kramer, 1984). When Milich and Kramer (1984) controlled for IQ in their statistical analyses they failed to find inhibitory problems for participants with ADHD. In contrast, other researchers have controlled for IQ using alternative EF measures, yet their results have continued to indicate inhibitory deficits in ADHD (Pennington & Ozonoff, 1996).

Factors such as age and IQ will affect temporal parameters, such as the length of time participants are able to focus on the test (Sonuga-Barke, 1995a). When temporal parameters are adapted to take into account the child's age and abilities, and the motivation and rewards for taking part in the test are adapted to be suitable for use with children, Sonuga-Barke (1995a) suggested that children with ADHD perform better than on traditional tests. The potential effects of temporal parameters, motivation and rewards on performance have been discussed by several other researchers (Douglas & Parry, 1994; Jennings *et al.*, 1997; Nigg, 2001; Sanders, 1983).

Also of concern is the issue of gender differences. Studies have tended to use predominantly male participants, a factor that has often not been thoroughly considered when interpreting findings. The issue of gender was investigated by Houghton *et al.* (1999) on the basis that earlier research had failed to look at differences or presented inconsistent results. For example, Siedman *et al.* (1997a; 1997b) concluded that boys with ADHD showed significantly greater impairment on tests of executive function than girls, but Gaub and Carlson (1997) found no significant differences in executive function test performance of girls and boys with ADHD. Houghton *et al.* (1999) failed to find any significant influence of gender on performance on executive function tests.

Additionally criticism can be directed at the failure of research using EF measures to control or account for the presence of co-morbid disorders (Oosterlaan *et al.*, 1998a; 1998b; Ozonoff, 1997). It is well documented that ADHD features co-morbid disorders including reading disability, conduct disorder, depression and Tourette syndrome (Barkley, 1990, 1994, 1998; Biederman *et al.*, 1991; Pennington & Ozonoff, 1996). Co-morbid disorders are such a common feature of ADHD that it is certainly possible that their presence may contribute to or even account for performance on EF tasks (Nigg, 1999). This highlights the need for any examination of inhibitory deficits in ADHD to consider carefully the impact of co-morbidity (Jensen *et al.*, 1997; Nigg, 1999; 2001).

3.5 The Research Proposal

In the present thesis attempt was made to design and utilise a methodology that facilitated focused study of the role of context in the performance and behaviour of children with ADHD. It became evident from the available literature, as discussed in this chapter, that to study one element of cognition, particularly inhibitory control, in isolation is likely to be very problematic. It was therefore eventually decided that the aim would be to investigate the wider performance and behaviour of children with ADHD, and then to

assess the extent to which any enhancements in performance could be attributed to improvements in executive function and specifically inhibition.

In addition the aim was to avoid using traditional EF measures that have been criticised on several levels. The assumption was made that early laboratory measures may act to underestimate 'real life' competence, particularly where the experimental setting reduces the complexity and range of contextual factors involved in 'real life' action. The present research acknowledged the importance of distinguishing performance in experimental settings from underlying competence. In order to attempt to look more closely at context dependent competence and performance in more 'real life' settings one of the aims of the method employed was to be as naturalistic as possible. In brief, the aim was to observe these children doing something that they are seen to engage with in their everyday lives, and to then try to pick apart factors that may have contributed to performance.

Given that children with ADHD appeared to show a particular interest in playing computer games, this provided the opportunity to look at abilities in a more naturalistic setting.

The aims of the study were therefore to examine performance of children with ADHD in two ways, in terms of the types of errors they make and the behavioural activity exhibited while engaging in a series of computerised tasks and commercially available games.

The present research was therefore conducted to systematically explore the performance of children with ADHD by examining their engagement with computer games and computerised tasks designed to extract features of computer games, particularly those thought to impact on inhibition. In addition, it was felt that the influences of enjoyment and motivational state required investigation.

In order to examine the anecdotal reports and to establish whether the proposed focus on computer games merited further investigation an initial study was carried out to look at the incidence of computer game playing among children with and without ADHD. This is

reported in Chapter 4. An investigation into specific games of interest, and their particular characteristics was also conducted and is reported in Chapter 5.

It was then necessary to investigate more directly the performance of children with ADHD. A series of systematic investigations into features of computer games and their impact on computerised task performance was then conducted and is reported in chapters 6, 7, 8 and 9. For these studies a suitable computerised task that provided measures of the types of cognition said to be difficult for children with ADHD was required. After much debate the Conner's CPT II was chosen as a task that was both practical and suitable for use across settings and in children's homes (it could be easily installed on portable computing equipment, and run by a single experimenter in a range of rooms in the participant's home in the presence of other distracting auditory stimuli). The CPT is reported to be a unique measure of attention and impulsivity (Grant *et al.*, 1990). The CPT requires the participant to maintain attention and respond to a continuously presented set of non-target stimuli, which in the Conners' CPT are letters presented at intervals of 1, 2 and 4 seconds. On the presentation of a target stimulus the participant must withhold their response. The participant must re-engage the primary response as soon as the next non-target stimulus appears.

The computerised CPT output measures and distinguishes between errors resulting from poor orientation to the task (failure to respond), or delayed responding and errors resulting from failure to withhold an ongoing, prepotent response (omission and commission errors respectively). High omission errors indicate inattentiveness and high commission errors indicate impulsivity (Conners, 1994). In this respect tasks such as the CPT can be useful for measuring specific types of executive functioning deficits faced by those with ADHD. The CPT is increasingly used as a clinical and diagnostic tool in the assessment of ADHD for this very reason. Omission and commission errors have consistently been said to illustrate impulsive responding and inattention in ADHD

(Barkley, 1999; Corkum & Siegel, 1993; Losier *et al.*, 1996; Epstein *et al.*, 1998; Shaw & Giambra, 1993; Barkley *et al.*, 1996). The CPT also has the benefit of not being temporally affected by a delay aversive response style as the task lasts for a set length of time.

Individuals with ADHD have consistently been reported to exhibit poor performance on continuous performance tests (Aman & Turbott, 1986; Barkley *et al.*, 1992; Barkley *et al.*, 1990; Brown & Wynne, 1982; Carte *et al.*, 1996; Grodzinsky & Diamond, 1992; Keogh & Margolis, 1976; Quay, 1997). They produce both more omission and more commission errors than control groups (Barkley *et al.*, 1996; Corkum & Siegel, 1993; Epstein *et al.*, 1998; Losier *et al.*, 1996; Shaw & Giambra, 1993). McGee *et al.* (2000) reported that the CPT has several important strengths. In particular they found that performance on the task was not correlated with age, there were no effects of order or fatigue, motor competence, visual processing speed, socio-economic status or gender. Performance also corresponded to other measures of sustained attention and was not confounded with co-morbid anxiety or conduct problems.

However, McGee *et al.* (2000) reported that despite the CPT's strengths it has some important weaknesses that must be considered. These were concerned with the 'overall index' summary of performance provided by the measure rather than the individual omission or commission scores. Criticism has also been aimed at the use of letters. As such the Conners' CPT relies on reading ability, if presented visually, and phonological awareness, if presented auditorally.

In addition to performance as measured on the CPT II it was decided that observations of the types of behaviour exhibited by participants while completing the computerised tasks would give a further index of performance. For this reason an observation procedure was selected to promote more informal, 'dynamic', assessment of cognition.

Finally, in light of the criticisms aimed at previous research with children with ADHD concerning issues of participant selection, it was decided that participants with ADHD should be matched as closely as possible with typically developing controls in terms of their non verbal IQ and experience on computers and computer games. Furthermore, these factors would be worked into statistical analyses as a covariate where possible, as would details about the co-morbid disorders experienced by the participants with ADHD.

Chapter 4

Study 1. Parental reports of behaviour and activity of children with ADHD and TD children in everyday settings, when engaged with activities of interest and when playing computer games.

4.1 Introduction

As discussed in the previous chapter, despite overwhelming empirical support for a deficit of inhibition in ADHD, there is a small amount of anecdotal evidence that when playing computer games problems of inhibition can be somewhat reduced or temporarily overcome. Given the implications these reports may have for a greater understanding of the role of context in the performance and behaviour of children with ADHD it seemed crucial that research in this area was carried out.

This initial investigation asked parents to report the nature of their child with ADHD's engagement with video/computer games through a series of structured questions. The first aim of the study was to examine whether the anecdotal reports that children with ADHD show an interest in playing computer games could be substantiated. The second aim of the study was to explore indications of the performance and behaviour of children with ADHD when playing computer games. In order to do this parents were asked to report how their children behave when playing computer games, in everyday situations and when engaging in other activities of interest to them.

Based upon the claims discussed above it was predicted that, relative to reports from the parents of typically developing children:

- parents of children with ADHD would report that their children experience problems of inhibition in daily settings;
- parents of children with ADHD would report that their children show a particular interest in playing computer games;
- parents of children with ADHD would report a significant improvement in the inhibitory behaviours of their children when playing computer games, especially compared to when engaging in other activities of interest.

4.2 Method

4.2.1 Questionnaire Design

Two questionnaires were designed, one for parents of children with ADHD and one for parents of typically developing children. Both questionnaires contained twenty-three questions asking parents to indicate their child's general behaviour in different situations and their child's main interests and behaviour when engaging in these activities of interest. Questions 1 to 4 asked parents to indicate their child's name, and address, date of birth and gender. Questions 5 to 15 asked parents to reflect upon their child's behaviour in everyday settings, this incorporated questions about their ability to concentrate, sit still, pay attention, focus and resist distractions in different settings and at different times of the day. Parents were asked to rate the degree to which different settings or stimuli distracted their child and were asked to indicate the degree to which their child found it more difficult or easier to concentrate across different settings. They were asked to list and discuss any circumstances in which their child shows a great deal of interest in an activity and to note any changes in behaviour while engaging with this activity. Questions 16 to 22 asked more specifically about computer games. Parents were asked whether their child showed an interest in playing computer games, and if so further questions were asked about the types of games their child showed an interest in and about their child's behaviour when playing these games. Questionnaires sent to parents of children with

ADHD contained four additional questions. These extra questions asked about diagnosis of ADHD, occurrence of co-morbid disorders, whether the child was receiving medication and performance on computer games whilst receiving this medication. In total the questionnaire sent to parents of children with ADHD consisted of twenty-seven questions (Appendix 1), the questionnaire sent to the parents of typically developing children consisted of twenty-three questions (Appendix 2).

4.2.2 Procedure

Prior to the main study the questionnaire was given to twenty parents of local primary school children in order to pilot it and identify any problems with its structure. As no significant problems were identified the study proceeded to the distribution of questionnaires. After consent was obtained from the Headteacher of a local primary school, two hundred and fifty questionnaires were distributed to parents of typically developing children between the ages of 4 and 13 years. The questionnaires for parents of children with ADHD between the same ages were distributed via an ADHD assessment centre and three support groups. A total of two hundred and fifty questionnaires were distributed between the different support groups and the assessment centre. Unfortunately the total number of questionnaires given to parents is unknown as the organisations involved did not record how many questionnaires they each distributed.

A total of thirty-five questionnaires from parents of children without ADHD and thirty-eight questionnaires from parents of children with ADHD were returned. However, several of these questionnaires were not suitable for use in the study due to large sections of partially or incorrectly completed responses or due to the child falling outside the age range of 4 to 13 years. A decision was therefore made to include thirty questionnaires from each group of parents. These were randomly selected. The parents' responses to the questionnaires were considered in terms of the characteristics of the children, incidence

of computer game playing, and behaviour whilst playing computer games in comparison to behaviour whilst engaging in other activities of interest.

4.2.3 Participants

The children ranged from 4 to 13 years, with a mean age of 10 years for the children with ADHD and 8 years 1 month for the typically developing children. As the sample depended on the parents' decision to complete and return the questionnaire, no attempt was made to control for age, gender or individual differences such as co-morbid disorder. Of the children with ADHD, 24 were male and 6 female. Of the typically developing children 13 were male and 17 were female. Of the children with ADHD, 13 were reported to have co-morbid disorders. The co-morbid disorders noted were dyslexia (5); oppositional defiance disorder (2); autism, including Asperger's, (3); obsessive compulsive (2); conduct disorder (1); dyspraxia (1); Tourette's syndrome (1); learning disability (1) and various language and communication problems (2). Of the children with ADHD, 26 out of 30 had been prescribed medication for their condition.

4.3 Results

4.3.1 Participant Characteristics

All parents of children with ADHD (30) reported that their children had difficulties concentrating, sitting still and paying attention and had problems concentrating on one thing at a time. In comparison the majority of parents of typically developing children (17) reported that their child did not have difficulties concentrating, sitting still and paying attention and (24) did not have problems concentrating on one thing at a time. Chi-square analyses revealed that the responses given by the 2 groups of parents to these questions were significantly different ($\chi^2 = p < 0.001$). Significantly more parents of children with ADHD than parents of typically developing children also reported that their children were more distracted by visual stimuli, ($\chi^2 = p < 0.001$); auditory stimuli, ($\chi^2 = p < 0.001$), visual and auditory stimuli combined, ($\chi^2 = p < 0.005$), other people, ($\chi^2 =$

$p < 0.001$), objects or materials nearby, ($\chi^2 = p < 0.001$), and other activities, ($\chi^2 = p < 0.001$).

These reports showed clear differences between the general behaviours of the two groups of children and confirmed the diagnostic groupings of the children.

4.3.2 Incidence of Computer Game Playing.

All responses given by parents of children with ADHD indicated that their children showed an interest in playing computer/console/video games. In contrast, five parents of typically developing children reported that their child did not show an interest in playing computer/console/video games (these children were excluded from later analyses). Chi square analysis revealed this difference between the types of responses given by the different groups of parents to be significant (ADHD 28 'yes' and 0 'no'; TD 24 'yes' and 5 'no'; $\chi^2 = 5.29$; $df = 1$; $p < 0.05$). When asked to list activities of interest and activities upon which their child concentrated for longer than on most other activities, more parents of children with ADHD (21 in total) spontaneously listed computer games than parents of children without ADHD (7 in total).

4.3.3 Behaviour

Parents were asked a series of questions about their children's behaviour both when engaged in activities of interest and when playing computer games compared to when engaged in most other activities. Table 1 summarises the responses of the parents to these questions. For some questions data were missing (i.e. less than 30 responses) where individual respondents failed to answer.

Table 1.

Per centage of parental responses given to questions about the child's behaviour in relation to most other activities when a) their child shows a great deal of interest in an activity and b) when playing computer games.

		a)Activities of Interest		b) Computer Games	
Response		ADHD	TD	ADHD	TD
Does your child seem to be able to concentrate and focus on the task for longer?	Yes	97%	93%	87%	50%
	No	0%	0%	3%	27%
	Missing	3%	7%	10%	23%
Does your child appear to perform better?	Yes	90%	93%	70%	27%
	No	3%	0%	6%	50%
	Missing	6%	6%	20%	23%
Does your child appear to be less impulsive?	Yes	67%	60%	53%	33%
	No	27%	27%	33%	43%
	Missing	6%	13%	13%	23%
Does your child appear to be less distractible?	Yes	73%	87%	80%	47%
	No	23%	3%	10%	30%
	Missing	3%	10%	10%	23%

Activities of Interest

Where children were reported to show a great deal of interest in an activity no significant differences were found between responses given by parents of the two groups of children for three of the four questions asked. The majority of parents from both groups indicated that their children seemed to be able to concentrate and focus on the task for longer, appeared to perform better and appeared to be less impulsive than on most other activities. However, although the majority of parents of both typically developing children and those with ADHD said their child was less distractible on this activity of interest than on most other activities, more of the parents of children with ADHD reported that their child was no less distractible. This difference in the amount of parents who were reporting no change in distractibility was significant (ADHD 22 'yes' and 7 'no'; TD 26 'yes' and 1 'no'; $\chi^2 = 4.77$; $df = 1$; $p < 0.05$).

Computer Games

In terms of behaviour when playing computer games several significant differences were found between the responses given by the parents of the two groups of children. These differences occurred for questions concerning: concentration and focus on task (ADHD 26 'yes' and 1 'no'; TD 15 'yes' and 8 'no'; $\chi^2 = 8.13$; $df = 1$; $p < 0.01$), with more parents of children with ADHD reporting greater concentration and focus on computer games; performance (ADHD 21 'yes' and 3 'no'; TD 8 'yes' and 15 'no'; $\chi^2 = 13.81$; $df = 1$; $p < 0.001$), with more parents of children with ADHD reporting greater success on computer games; and distractibility (ADHD 24 'yes' and 3 'no'; TD 14 'yes' and 9 'no'; $\chi^2 = 5.35$; $df = 1$; $p < 0.05$), with more parents of children with ADHD reporting less distractibility on computer games. It is particularly interesting to note that where the majority of parents of typically developing children felt that their child's performance improved when engaging with activities of interest they did not feel that their child's

performance improved when playing computer games. This contrasted sharply with the reports given by parents of children with ADHD.

More parents of children with ADHD reported that their children appeared to be less impulsive when playing computer games than on most other activities (16 ‘yes’ and 10 ‘no’), while more parents of typically developing children reported that their children did not appear to be less impulsive (10 ‘yes’ and 13 ‘no’). However, this difference between the responses given by the 2 groups of parents was not statistically significant.

4.3.4 Attitude and Ability when Playing Computer Games

Parents were also asked more specific questions about their child’s attitude, abilities and behaviour when playing computer games. Table 2 summarises the responses of the parents to these questions.

Table 2.

Per centage of parental responses to the questions concerning their child’s attitude, abilities and behaviour when playing computer games.

	Responses	Children with ADHD	Typically Developing Children
a) Is your child more motivated when playing these games?	Yes	83%	43%
	No	6%	30%
	Missing	10%	27%
b) Is your child more mentally active when playing these games?	Yes	84%	50%
	No	6%	27%
	Missing	10%	23%
c) Is your child less physically active when playing these games?	Yes	73%	64%
	No	17%	13%
	Missing	6%	23%
d) Is your child able to stop and think more before acting when playing these games?	Yes	50%	50%
	No	33%	27%
	Missing	17%	23%

Again, it is important to note that some data are missing where participants did not respond to every question.

Differences between patterns of yes and no responses given by the parents of the two groups of children emerged for two of the above questions. More parents of children with ADHD than parents of TD children indicated that their children appeared more motivated (ADHD 25 'yes' and 2 'no'; TD 13 'yes' and 9 'no'; $\chi^2 = 7.82$; $df = 1$; $p < 0.005$) and more mentally active when playing these games (ADHD 25 'yes' and 2 'no'; TD 15 'yes' and 8 'no'; $\chi^2 = 5.82$; $df = 1$; $p < 0.05$).

4.4 Discussion

4.4.1 Summary of Findings

The present study supported the well-established finding that children with ADHD experience problems of inhibition (being able to sit still, concentrate and pay attention) in daily settings. The results of this study also provided support for the main hypothesis under investigation. All parents of children with ADHD reported that their children showed an interest in playing computer games. Furthermore, findings indicated improvements in the inhibitory behaviours (concentration, focus, sustained attention, performance) of the children with ADHD when playing computer games.

What was particularly interesting about the reports given by parents of children with ADHD of their children's behaviour when playing computer games is that they differed from the reports given when the children were engaged with other activities of interest. Results suggested that on other activities of interest children with ADHD remain more

distractible than typically developing children. In direct contrast, when playing computer games, significantly more children with ADHD were rated as less distractible. Barkley (1997b) referred to distractibility as a form of interference control, an important feature of inhibition.

In summary, parental reports suggested that when playing computer games children with ADHD exhibit executive abilities that they do not demonstrate in daily settings or on other activities of interest. This raised questions concerning the nature of the hypothesised inhibitory deficit. The reported improvements suggested that inhibitory control appears to improve in these children with ADHD when playing computer games. This therefore substantiated claims that there is a paradox in the observations of the abilities of children with ADHD and suggested that the rationale for the proposed programme of research for this thesis was well founded.

This investigation did not challenge claims that there is inhibitory dysfunction in ADHD, it simply suggested that there may be circumstances in which some inhibitory problems may be overcome. Findings lent support to context dependent theories of ADHD where inhibitory control and thus executive function is said to be determined by the relationship between environmental, task and personal factors such as reinforcement, motivation, stimulation and cortical arousal. Children with ADHD were reported to be more motivated and more mentally active when playing computer games.

The present finding from this exploratory study therefore raised some interesting questions about the features of computer games that make them attractive to children with ADHD and that may impact on inhibitory performance. An essential feature of the computer game is that it is indeed a 'game'. Reiber (1996) argued that the playing of games is an intrinsically motivating activity which 'involves some level of activity and often possesses make-believe qualities'. This may be one of the most important factors affecting the child with ADHD's inhibitory abilities when playing these games.

4.4.2 Conclusions

The initial investigation conducted in Study 1 was a report of parental attitudes and opinions on behaviour and abilities and as such did not facilitate examination of the factors listed above. Study 1 did not provide direct observation of the abilities and behaviour of children with ADHD while playing computer games. As such it was limited in terms of wider application. This study therefore pointed to the need for direct observation of the behaviour of children with ADHD when playing computer games. This would allow examination the inhibitory performance of children with ADHD and examination of some of the features of computer games and their impact on cognitive performance. This was explored in the following studies. Study 2 explored parental views and studies 3, 4, 5, 6, and 7 observed the performance of children with ADHD and TD children on a series of computerised tasks designed to encapsulate key features of computer games. Study 8 examined the performance of children with ADHD and TD children on 2 commercially available games.

Chapter 5

Study 2: Views Expressed by Parents

5.1 Introduction

The findings of Study 1 clearly indicated that parents of children with ADHD felt that their children show a significant interest in computer games that was not demonstrated by parents of TD children. In order to examine the views of parents with ADHD in more detail and in order to gain more of an insight into a range of features that might promote interest in computer games an exploratory study was therefore conducted. Parents of the children with ADHD and parents of TD children were interviewed and their responses compared.

5.2 Method

5.2.1 Design

Semi-structured interviews for parents were designed to examine whether there might be any suggestive patterns that might support the intention to examine in more detail the performance and behaviour of children with ADHD on computer games. In particular, this study was designed as a preliminary examination of the types of computer games found to be the most interesting and the factors believed to contribute to this interest. The aim was also to investigate issues connected with the speed of the game, and its impact on the child's interest, enjoyment, success and attention.

5.2.2 Participants

Eighteen parents of children with ADHD between the ages of 4 to 16 years, with a mean age of 8 years and 8 months (SD 2.8), were interviewed. None of these parents had taken part in Study 1. The majority of parents, 10, took part in the informal interview alone, eight were accompanied by their partner. Eighteen parents of TD children were also

interviewed. Their children were also between the ages of 4 and 16 years, with a mean age of 8 years and 3 months (SD 2.9). Table 3 below summarises the characteristics of the children of the parents interviewed.

Table 3.

Characteristics of the participants' children with ADHD and TD children: age, gender, general level of experience on computer games and co-occurring disorders.

	Mean age	Level of experience with computer games	Child's co-occurring disorders	Gender
ADHD	8y 8m	Experienced	Combinations of LD, ODD,	17 Male
			DCD, Asperger's Syndrome,	1 Female
			Autistic Spectrum Disorders	
TD	8y 3m	Experienced	None	17 Male
				1 Female

5.2.3 Procedure

Informal interviews were conducted with parents on a voluntary basis. Parents of children with ADHD were identified and recruited from the Learning Assessment Centre, a multidisciplinary centre specialising in the assessment and treatment of ADHD, on the basis that their children were interested in playing computer and console games. Parents of typically developing children were recruited from mainstream schools after school clubs and playschemes on the basis that their children had no history of ADHD or co-morbid disorders, and that they were interested in playing computer and console games.

The experimenter approached each set of parents, or individual parent, separately and explained the purpose of the investigation and what involvement would be required. If parents indicated an interest in taking part in the investigation, and if their child met the requirements stated above, their details were noted by the experimenter. They were

then asked six main questions but were invited to expand the discussion to issues they felt were relevant. The questions were as follows:

Q1. Can you list the types of computer games that your child finds the most interesting?

Q2. Can you list and discuss factors you believe might contribute to your child's interest in playing computer games.

Q3. How important do you think the speed of computer games is in terms of making it interesting for your child?

Q4. Can you indicate the speed of game you believe your child enjoys most from the following speeds: Slow, Medium, Fast and Very Fast.

Q5. Can you indicate the speed you believe helps your child to be most successful from the same speeds: Slow, Medium, Fast and Very Fast?

Q6. Lastly can you indicate the speed of game you believe holds your child's attention best from the same list of speeds: Slow, Medium, Fast and Very Fast?

Following the last question parents were thanked for their participation and were asked if they would like to receive a summary of the results after completion of the study. The results were examined, organised and categorised by the experimenter on completion of the last interview.

5.3 Results

5.3.1 Question 1: Games Parents Believed Their Children Find Most Interesting.

Responses fell into the following broad categories: Action/Adventure, Any/All, Combat, Driving, Educational, Platform, Puzzle, Racing, Simulation, and Sports. Figure 5 indicates the main categorisation of responses, although there was overlap and parents often listed more than one type.

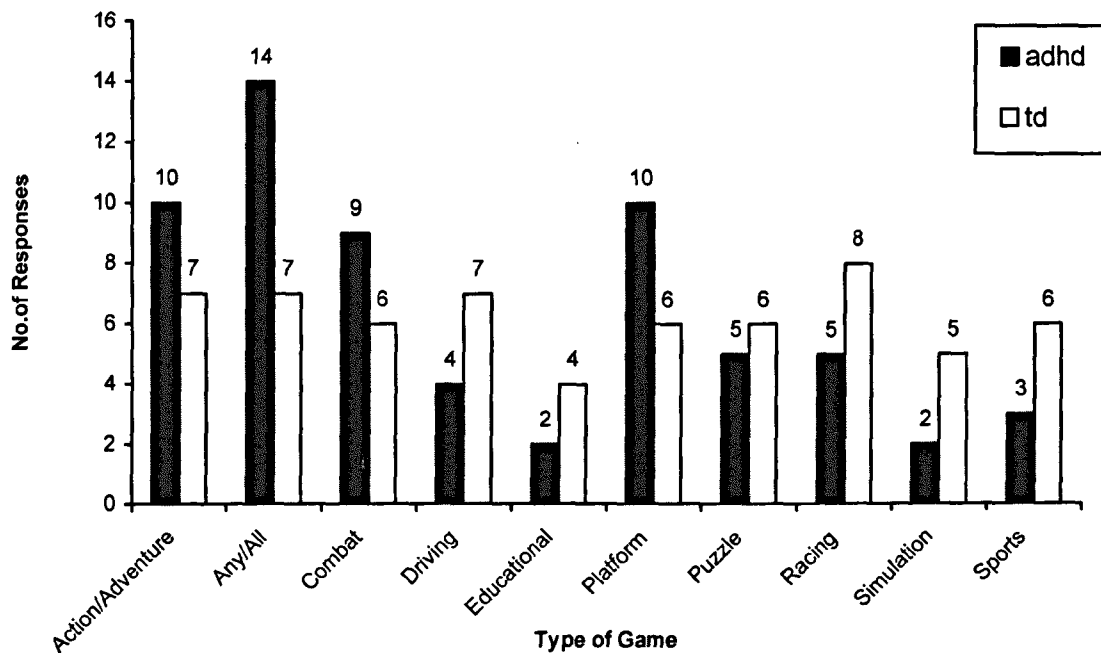


Figure 5. Types of games listed as most interesting to children with ADHD and TD children by their parents.

There were some interesting trends revealed by this question and these are summarised in greater detail below, however, chi square analysis conducted on the responses given by the two groups of parents did not reveal a significant association between the type of parent and the types of game they listed as most interesting to their children.

The following section summarises the responses given by both groups of parents to the question ‘Can you list the types of computer games that your child finds the most interesting?’. The most frequently listed type of game for children with ADHD was ‘any or all’ types. Parents of children with ADHD commented that their children showed a strong desire to play any type of game and that this was their favourite activity. In contrast parents of TD children reflected that their children had more specific interests and that if a particular game was not available they would choose to engage with an alternative activity. Parents of TD children more often reported that their child’s gameplay was dictated by whether or not they had the latest ‘most fashionable’ game and the likes and dislikes of their friends. As a consequence the most frequently listed game by parents of TD children was racing, followed closely by the categories of

action/adventure; any; and driving, all of which received the same number of responses. Similarly, the third most frequently listed categories by parents of TD children: combat, platform, puzzle and sports all received the same frequency of listing, and were closely followed by the category simulation and lastly educational.

The second most frequently listed game by parents of children with ADHD was platform games, followed by action/adventure games. These types of games were those described by parents as fast moving but level orientated, the child could choose to play at a level appropriate to their skill and progress up to levels as they gained new skills. Many parents reflected that their children seemed determined to beat the level and get on to the next and that they would play continuously until they achieved this, however parents of children with ADHD most frequently mentioned this factor. In general parents of children with ADHD responded that this was usually achieved in a relatively short time, but all parents reflected that sometimes their child would become very frustrated and would become aggressive or agitated. However, the types of responses to this frustration reported by parents of children with ADHD tended to be more exaggerated, their children were reported to lash out at the computer or console and sometimes to break equipment. All parents reported that their children seemed concerned with how successful peers or siblings were on the game. More parents of children with ADHD reported that their child would sit still and focus for a long time on these games. More parents of TD children mentioned the fact that their child's gameplay seemed to be guided by social factors, such as when, where and what their friends were playing. More parents of TD children said that their child preferred to play with a sibling or friend.

The next most frequently listed game of interest for children with ADHD was combat or fighting games. Parental responses to these games were varied. Whilst some parents from both groups reflected that they were concerned about their child's interest in violence or aggression, parents of children with ADHD tended to report that they felt that playing

these games helped to release frustration. Some parents of children with ADHD reflected that their child tended to choose these sorts of games when they were angry, frustrated or 'having a bad day'. Other parents of children with ADHD reported that these types of games sparked conflict at home as their child had attempted to replicate fight scenes with peers or siblings. In contrast to adventure, platform or puzzle games parents of children with ADHD reported that these combat/fighting games made their child more animated and active when they played them.

Puzzle and racing based games were the next most frequently listed games by parents of children with ADHD, followed by driving, sports, simulation and finally educational games. Again all parents of children with ADHD reported that their children would focus and attend to these sorts of games. The choice of game for children with ADHD appeared to be specific to the individual child, with all parents reporting that game choice reflected wider personal interests, such as formula 1 or football. All parents again reported that the racing, driving and simulation games tended to be very fast moving. All these games, with the exception of puzzle games, were reported by parents to be very realistic. Parents of children with ADHD reported that their children liked to do activities that they do in real life, such as skateboarding, bike racing, playing football. In contrast, and as mentioned above, parents of TD children more often discussed the fact that their child was influenced by peers and current fashions and therefore liked to do whatever was 'in' at the time.

5.3.2 Question 2: Factors Parents Felt Contribute to their Child's Interest in Computer Games.

Parents listed several factors as contributing to their child’s interest in playing computer games. From these several categories were devised. These are listed in Figure 6:

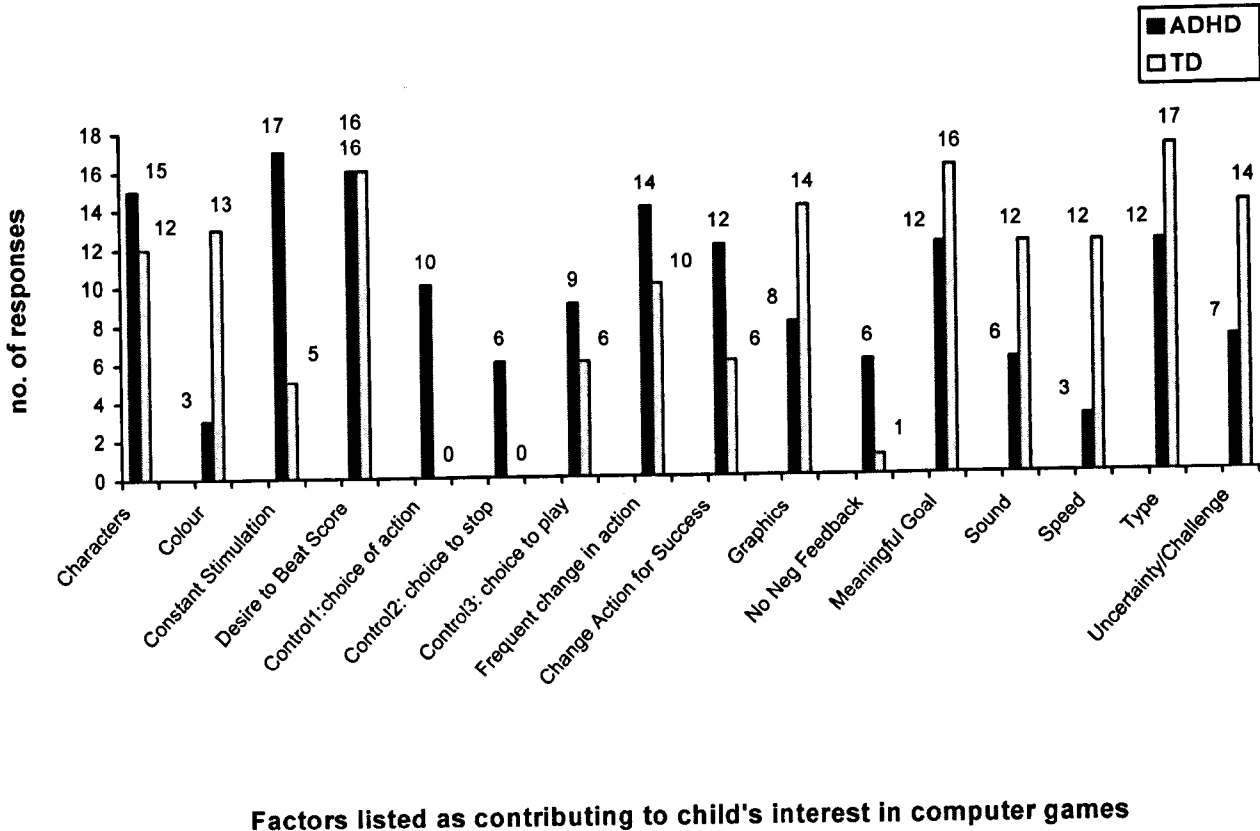


Figure 6. Number of parents with ADHD and parents of TD children who listed each of the features said to contribute to their child’s interest in computer games.

Chi square analysis conducted on this data revealed a significant association between the type of parent and the factors they listed as contributing to their child’s interest playing computer games ($p<0.001$). The most frequently listed factor believed to contribute to the child with ADHD’s interest in playing computer games was constant stimulation. In contrast far fewer parents of TD children rated this factor as contributing to their child’s interest. Parents of TD children rated the type of game most frequently as contributing to their child’s interest. The second most frequently listed feature of parents of children with ADHD was the desire to beat a previous score of that of other players, parents of TD

children also rated this feature second most frequently. Character was the feature listed third most frequently by parents of children with ADHD, followed by frequent change in the action on screen as the fourth most listed feature. In contrast parents of TD children rated meaningful goal, third most frequently followed by the elements of uncertainty and challenge. The rest of the features were listed in the following order by parents of children with ADHD: meaningful goals, type of game and frequent change in action or response required, control over direction of action within the game, control over choice to play, uncertainty about outcome, lack of negative feedback, type of sound and graphics and lastly colour and speed. In contrast parents of TD children selected the features in the following order of frequency: graphics, colour, speed and sound, frequent change in action or response required and control over choice to play, constant stimulation, and lastly lack of negative feedback. The features control over direction of action within the game and control over choice to stop playing were not listed at all by parents of TD children.

5.3.3 Questions 3, 4, 5 & 6: Speed of Game Play

Many of the parents of children with ADHD indicated that they thought speed of game play influenced their child's interest in computer games. Parents of TD children listed this feature less frequently. The speeds indicated as most enjoyed, most helpful for success and best for holding their child's attention by parents of children with ADHD and parents of TD children are presented in Figure 7.

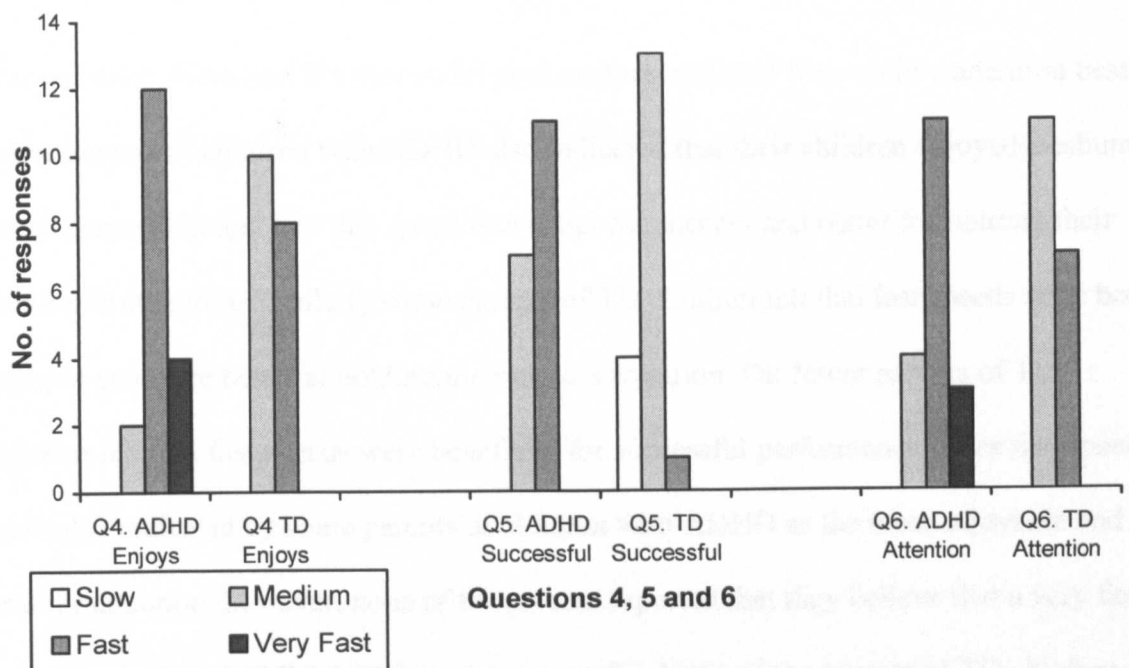


Figure 7. Speeds listed as best for their child's enjoyment, success and attention on computer games by parents of children with ADHD and TD children.

Analyses using the Mann Whitney test revealed a significant difference between the responses given by the two groups of parents to Question 4 'Can you indicate the speed of game you believe your child enjoys most from the following speeds: Slow, Medium, Fast and Very Fast?', ($z=-3.131$; $p<0.005$), a significant difference between the responses given by the two groups of parents to Question 5: 'Can you indicate the speed you believe helps your child to be most successful from the same speeds: Slow, Medium, Fast and Very Fast?', ($z=-3.700$; $p<0.001$), and a significant difference between the responses given by the two groups of parents to Question 6: 'can you indicate the speed of game you believe holds your child's attention best from the same list of speeds: Slow, Medium, Fast and Very Fast?', ($z=-2.596$; $p<0.01$).

The majority of parents of children with ADHD indicated that their children enjoyed fast moving games best, and the majority of these parents also indicated that this speed helped their children to be most successful and was better for holding their children's attention. In contrast the parents of TD children indicated that games of medium speed were

enjoyed most, were best for successful performance and held their child's attention best. Some parents of children with ADHD also indicated that their children enjoyed medium speed games best and that this speed was better for success and better for holding their children's attention. Similarly some parents of TD children felt that fast speeds were both enjoyed and were better at holding their child's attention. Far fewer parents of TD children felt that fast speeds were beneficial for successful performance. Very fast speeds were also indicated by some parents of children with ADHD as the most enjoyable and best for attention, however, none of the parents reported that they believe that a very fast speed allowed their children to be most successful. None of the parents of TD children felt that very fast speeds influenced their child's enjoyment, success or attention. None of the parents of children with ADHD reported that they thought slow games were most enjoyable for their child, none of the parents indicated that slow speed was better for success and again none of the parents indicated that they felt a slow speed was best for holding their children's attention. In contrast some parents of TD children felt that a slow speed may be best for their child's success, more parents of TD children rated this speed than fast speeds.

5.4 Discussion

Parents gave some interesting insights into their beliefs concerning the nature of computer games and their effects on their children both with and without ADHD. Views expressed during the interviews concerning the types of game that parents believed their children found most interesting indicated that parents of children with ADHD believed their children show a specific interest in playing any or all types of games. This finding confirmed the indication given by parents in Study 1. Some parents reported concerns about 'almost obsessive' interest in computer game playing. This was sometimes to the frustration or annoyance of parents, some revealed that they had concerns about lack of social interaction and conflict with siblings as the child with ADHD refuses to share, take turns and so on. Parents of TD children listed specific types of game more frequently

rather than all games, with racing games being listed followed by driving games and action games. There was little variation in the frequencies with which each of the categories were rated for the TD children. It is important to note however, that chi square analysis did not reveal a significant association between the type of parent and the types of game that they listed. Interestingly, parents of TD children indicated that computer game playing was quite a social activity, and that interest in games was influenced by peers and whether or not their friends or siblings chose to play. For these children game preference was often said to be influenced by social trends.

Children with ADHD were reported to be most interested in action, adventure, and platform types of games, as mentioned above these were also rated frequently by parents of TD children. Importantly all of the types of games listed most frequently by both groups are fast moving, colourful and interactive. They are orientated at differing levels of skill and contain elements of fantasy and pretence. This finding corresponds to the proposal of Malone (1981) who hypothesised that these elements are some of the most important in making a game fun. Game manufacturers specifically design games to encourage the player to want to keep playing and not to get bored. One of the ways they do this is to add levels to games. The child can therefore play at a level that allows him/her some success yet remains challenging. Parental reports reflected this desire to keep playing, desire to beat scores was the second most frequently mentioned factor by both groups of parents, children were reported to keep playing in order to beat either others or their own old scores and were reported to be concerned with how successful peers or siblings were on the game.

This suggests that the element of competition associated with computer games is a particularly motivating factor. Just under half of all parents also mentioned the element of challenge as one of the features contributing to their child's interest. It is possible that this is only true for tasks where perceived chance of success is high. Some parents of children

with ADHD reflected upon this factor and suggested that this may be one of the few contexts in which their child with ADHD feels they are successful.

Parents of both groups of children listed combat or fighting games as influential, although more parents of children with ADHD listed this feature. There may be several explanations as to why these games might be particularly attractive to this group of children. Firstly it may be that aggressive and oppositional tendencies, often found co-occurring with ADHD, lead these children to be attracted to games that are congruent with their general affective state. Alternatively it may be that the nature of the disorder leads to high levels of frustration and these types of game present a safe context in which to express or release negative feelings. However, this is certainly also a possibility for TD children.

It was interesting to note that several parents of children with ADHD reported that these games made their child more animated and active, this contrasts with parents of TD children who did not make such comments. Puzzle, racing, driving, sports and simulation games, were also listed by parents of children with ADHD. These games often reflect real world activities. Parents of children with ADHD reported that the types of games that their children like to play are often those that reflect activities they participate in such as skateboarding. It may be that in the computer game playing context the child becomes more competent at favoured activities as they can take more risks without suffering real world consequences. In this way these games allow the child to live out their fantasies and to escape real world limitations. However, it must be noted that more parents of TD children listed these games.

Parental reports may reflect the types of games marketed at the age group of their children, or game choices may reflect social influences and peer group norms, as indicated by the comments of parents of TD children. Findings of this study offer further

support for the claims made by theorists such as Malone (1980, 1981, 1984), Amory *et al.* (1999) and Ju and Wagner (1997).

Perhaps the largest difference in the responses of the two groups of parents concerned the influence of the level of stimulation of the game, as reflected by responses to Question 2, where a significant difference was found between the type of parents and the factors they listed as contributing to their child's interest in playing computer games. A large majority of parents of children with ADHD reported that the constant stimulation provided by computer games contributes to their child with ADHD's interest. Whereas relatively few parents of TD children felt that this feature was important. This was a particularly significant finding as it relates directly to one of the main theoretical accounts of ADHD. According to optimal stimulation theory individuals with ADHD suffer from low levels of stimulation, cortical arousal, activation and effort (Antrop *et al.*, 2000; Sanders, 1983, 1998; Sergeant *et al.*, 1997; van der Meere, 1996; Zentall, 1975). To re-iterate, this approach proposes that symptoms of ADHD, such as hyperactivity and impulsivity, arise as a result of understimulation and low levels of arousal. Consequently children with ADHD compensate by engaging in stimulation seeking behaviour (Antrop *et al.*, 2000; Zentall & Zentall, 1976; 1983). This was supported by the finding that frequent change in action was the fourth most frequently mentioned factor thought to contribute to the child with ADHD's interest in computer games, but was the ninth most frequently mentioned factor by parents of TD children.

Findings also indicated that the use of character was important for children with ADHD but not so important for TD children. This was the third most frequently mentioned factor by parents of children with ADHD but the eighth most frequently mentioned feature by parents of TD children thought to contribute to their child's interest. Character may help to make the task more meaningful for children with ADHD. Meaningful goals were listed by two thirds of parents as contributing to their child with ADHD's interest. However,

meaningful goals were also the third most frequently rated feature contributing to the TD child's interest in computer games. This is particularly relevant to the issue of the influence of context on cognition and was raised as one of the central criticisms of Piagetian tasks by McGarrigle and Donaldson's (1975).

The element of control was a factor mentioned far more frequently by parents of children with ADHD. Control was discussed in terms of choice of when to play, what to play, when to stop and the fact that this is not a task imposed by adults. This appeared to overlap with comments concerning the belief that computer games are the 'property' of children, that parents don't understand them or know how to play.

Whereas the features of graphics, colour, sound and speed were rated fairly frequently by parents of TD children, relatively few parents of children with ADHD indicated that they believed these features contributed to their child's interest in playing games. However, when asked specifically about speed the majority of parents of children with ADHD consistently reported that they felt fast games were those that were not only enjoyed the most by their children with ADHD, but also those that facilitated more successful performance and better attention. Yet again, analysis revealed that this differed significantly from the reports of parents of TD children who indicated that medium speeds were enjoyed most, were better for success and were the best for holding their child's attention. None of the parents from either group indicated that slow games were enjoyed the most or were best for holding attention. In addition none of the parents of children with ADHD felt that slow speeds aided success, however some of the parents of TD children felt that slow speeds might be the best for their child's successful performance. This finding corresponds to the claim that individuals with ADHD are stimulation seeking (Antrop *et al.*, 2000) and provides further support for cognitive energetic models of ADHD and Optimal Stimulation Theory (Zentall, 1975).

This study further supports the paradox in the observations of the performance and behaviour of children with ADHD while playing computer games compared to other settings. It also suggests that children with ADHD differ from TD children in their interest in, interaction with and successful performance on computer games. Parents of children with ADHD reported that their children were particularly interested in playing all types of games, but importantly, they indicated that they felt a range of contextual features contributed to this special interest. These features included specific characteristics of the game, such as level of stimulation, constant change in action and speed. Features such as sound and graphics, and the way in which the game was framed, for example whether there was the element of competition, the type of character used, the presence of a meaningful goal, and lack of negative feedback were reported as important by both groups of parents. Furthermore, the issue of control in this context seemed to be particularly important for children with ADHD, with parents reporting control of action, control over choice to play and the control over the final outcome as influencing their child's interest in computer games. In summary, the preliminary findings from Studies 1 and 2 illustrate the need to observe behaviour and examine performance in the context of the computer game playing setting. Contextual characteristics of the computer game playing setting, or features of the games themselves, appear to encourage increases in attention and concentration that are not commonly demonstrated by children with ADHD in other settings. Furthermore, the questionnaire studies have indicated that executive performance might also be enhanced in these settings. This raises questions about the way in which competence and performance are assessed and about the contextual features of computer games that elicit such responses. In conclusion, the findings of the two questionnaire studies add support to the claim that a stronger contextual focus is needed in subsequent studies of cognitive performance. The following investigation therefore used computerised 'game like' tasks to investigate the performance of children with ADHD and that of TD children.

Chapter 6

Study 3: Performance on computerised ‘game like’ tasks by children with ADHD

6.1 Introduction

The questionnaire study examined parental reports of the interests of children with ADHD and TD children and their behaviours while playing computer games. Parents reported that children with ADHD had problems of attention and concentration in daily settings (section 4.3.1). However, improvements in focus and concentration, higher levels of successful performance, a reduction in distractibility (section 4.3.3) and increased motivation and mental activity (section 4.3.4) were reported for these same children when playing computer games. In Study 2 parents of children with ADHD reported that there were particular features and characteristics of computer playing setting and the games that contributed to their child’s behaviour and performance. The findings of these studies highlighted a need for research into the abilities of children with ADHD when playing computerised games.

In particular these preliminary results raised some interesting questions about the executive performance of children with ADHD and conditions and contexts under which improvements may take place. Further exploration and direct observation of the performance of children with ADHD when playing computerised games was therefore proposed in this study. As outlined in Chapter 3, the aim of further investigation was to systematically explore the performance of children with ADHD by examining their engagement with standardised computerised tasks designed to measure executive function and attention, and to compare this performance to that exhibited on computerised tasks contextually manipulated to contain certain features thought to be

pertinent to computer games. The Conner's CPT II was chosen as the standardised task. The CPT II is reported to be a unique measure of attention and impulsivity (Grant *et al.*, 1990). Two main types of observation were planned, these included examination of the errors made by the children, and the behavioural activity exhibited while engaging with the computerised tasks.

The first aim of this study was therefore to compare performance in terms of error making on two computerised tasks. The first of these tasks was the Conners' Continuous Performance Test II (CPT II), developed to assess inattention and impulsive responding (Conners, 2000). The second task was a modification of this first task (the Conner's CPT II) designed to be more 'game like' in its presentation (containing features commonly found in computer games). The elements of computer games selected were the introduction of colourful, familiar cartoon characters and the introduction of a relevant and appropriate narrative that outlined the goal of the task and hopefully gave it meaning to the participants.

The second aim of the study was therefore to examine observational indices of performance exhibited whilst engaging with the computerised task and the more 'game like' version of this task. Observations were made of on-task activity, and off task activity (including distractibility, fidgeting, touching other objects in the room and out of seat activity).

Predictions made following the questionnaire study and informal interviews were that individuals with ADHD would display improvements in performance suggestive of improved inhibitory control on more 'game like' tasks. Results were expected to reflect the contextually dependent nature of performance and increases in both intrinsic and extrinsic motivation. It was therefore predicted that:

- there would be no difference in the performance and activity of TD participants across tasks;

but that in contrast participants with ADHD would:

- show fewer errors on a game version of the CPT II than on the standard CPT II;
- show a greater level of performance enhancement on a 'game like' task than would TD children; and
- would show more on-task activity when playing the more game like computerised task.

6.2 Method

6.2.1 Design

The study used a mixed design. The performance of participants with ADHD was examined across tasks and compared to that of TD children. The dependent variable was performance measured first in terms of errors of commission, and second, the amount of on-task activity exhibited. The number of commission errors made were investigated on two versions of the Conners' CPT II. It was intended that errors of omission would also be examined across tasks and between groups. However, unfortunately these data were lost due to a technical error.

The presentation of all tasks was counterbalanced to avoid order effects.

6.2.2 Participants

Sixteen children with ADHD and sixteen typically developing children were matched as closely as possible on general experience with computer games, and on experience with the games to be used in the study. The children were also matched on their Raven's Progressive Matrices Score as a measure of non verbal IQ. Of the children with ADHD 15 were male and 1 was female. The age of ADHD participants ranged from 6 years 8 months to 13 years 10 months, mean age 10 years and 4 months. Of the typically developing children 14 were male and 2 were female. The age of the typically developing children ranged from 6 years 5 months to 13 years 2 months, mean age 8 years 8 months.

Children with ADHD met the criteria for ADHD based upon the Diagnostic and Statistical Manual of Mental Disorders (APA, 1987; APA, 1994). All had been diagnosed prior to the study by a consultant paediatrician or psychiatrist. Parents also completed the Achenbach Child Behavior Checklist for ages 4 –18 and teachers completed the Achenbach Teacher’s Report Form for ages 5-18 (Achenbach, 1991). Only children with a confirmed diagnosis of ADHD who met the clinical cut offs on the Achenbach ratings were included in this study. In response to an initial letter sent to the children and their families, all participants indicated an interest in playing computer and console games. Half of the children with ADHD had co-occurring disorders, including Anxiety (1), Asperger’s Syndrome (1), Conduct Disorder (CD) (1), Dyslexia (1), Developmental Coordination Disorder (DCD) (1), Oppositional Defiance Disorder (ODD) (2) and Tics (1). The characteristics of the ADHD and TD groups are summarised in Table 4.

Table 4

Characteristics of ADHD and TD participants in terms of Age, Raven’s Progressive Matrices Score and General level of experience on computer games.

	Mean Age (SD)		Mean Ravens’ Progressive (SD) Matrices Score		General Level of Experience with Computer Games
ADHD	10.4 years	(2.0)	75 th per centile	(3.5)	Very experienced
TD	8.8 years	(1.9)	75 th per centile	(4.7)	Very experienced

6.2.3 Recruitment

Participants with ADHD were recruited from the Learning Assessment Centre, a multidisciplinary centre specialising in the assessment and treatment of ADHD, and support groups on the basis that they indicated an interest in playing computer and console games. Typically developing children were recruited from mainstream schools and playschemes located in the same areas as the children with ADHD. Typically

developing children were selected on the basis that they had no history of ADHD or co-morbid disorders, and indicated an interest in playing computer and console games.

6.2.4 Computer Tasks

Two computerised tasks were presented on a laptop. The *Conner's Continuous Performance Test II* (referred to as the CPT II) and a specifically designed game version of the CPT II (referred to as the *Pokémon* task).

The *Conner's CPT II* (Conners, 2000) provides measures of attention and impulsivity. The task lasts for 14 minutes and the participant must attend to computer generated letters presented at inter-stimulus intervals (ISI) of 1, 2, and 4 seconds, with a display time of 250 milliseconds. The participant must press the space bar in response to all letters apart from the target letter X. The computer programme records response times and error rates. Participants can make two types of error. Omission errors, when the child omits to press the spacebar in response to a letter, are said to reflect either failure to attend or slowness in responding to a letter. Commission errors, failure to withhold a response to the letter X, are said to reflect impulsive responding (Barkley, 1996b; Corkum & Siegel, 1993; Losier *et al.*, 1996; Shaw & Giambra, 1993).

The *Pokémon* task was designed as an isomorphic task in relation to the CPT II. Participants were asked to respond to *Pokémon* characters instead of letters. Characters were exactly the same size as the letters presented in the CPT II, were presented for exactly the same amount of time and at equivalent intervals. However, in contrast to the black and white letters used in the CPT II, characters were presented in colour. Target items were the character '*Pikachu*' instead of the letter X. Participants were instructed not to respond to '*Pikachu*'.

Both tasks were presented for a duration of 14 minutes.

6.2.5 The Setting

All participants were observed in an informal 'playroom' setting, similar to the rooms used by Handen *et al.* (1998) and Hughes (1998) for their playroom observations. For most participants this was a room in their home. As such this environment was familiar and contained many distractors including toys, a television, video, computer and so on. At the time of testing normal family life continued in the house, although others were excluded from the 'playroom'. The aim was to make the setting as informal and naturalistic as possible. For a few participants testing was in a specially modified playroom at the University or at the Learning Assessment Centre. This was furnished to reflect an informal 'home' setting. Again distracting objects, toys, television and video, pictures and so forth were placed in the room.

Children with ADHD who were prescribed medication abstained from taking their regular dose four hours prior to testing. They continued to take their medication as soon as testing finished. All children who had been prescribed medication were taking fast acting medications that are effective for approximately 4 hours, after which they require another dose. To abstain from medication for the duration required for testing therefore had a minimal impact on long term treatment and could be resolved as soon as testing had finished. However it must be acknowledged that performance may have been affected by residual methylphenidate. This was confirmed and approved by participants' consultant paediatricians and psychiatrists. Only participants whose parents also consented took part in the study.

6.2.6 Procedure

Before participants were presented with the tasks they completed the *Raven's Progressive Matrices* (Raven, 1988).

Participants were then asked if they would like to play some games on the laptop. If the participant responded positively the experimenter asked about their level of experience

with computer games. Possible responses were 'none', 'a little', 'somewhat', 'experienced' or 'very experienced'. Consultation with parents was used to confirm level of experience. Interest and familiarisation with *Pokémon* and the character '*Pikachu*' was also ascertained. All children were both interested and familiar with the cartoon and the characters.

The presentation of tasks was counterbalanced. Participants were given clear instructions and the experimenter demonstrated what was required.

For the CPT II the experimenter explained 'The computer will show lots of letters on the screen one at a time. You will need to press the spacebar for all of the letters that you see except for the letter X, the one which looks like this.... . Please press the spacebar as quickly but also as accurately as possible. Remember please press the spacebar for any letter you see apart from the X. First we will have a quick practice session and then I will let you play the whole game. The game will last for 14 minutes. When you click the OK button, the session will start'.

For the *Pokémon* game the experimenter told a brief story giving a reason for not responding to *Pikachu*: 'the idea of the game is to catch as many *Pokémon* as you can. You will see a *Pokémon* character appear on the screen and in order to catch it you must press the space bar as quickly as possible, like this. All the *Pokémon* you catch will be kept in their *Pokeballs*. But there is one problem. *Pikachu* is feeling a bit naughty today. He will free all of your *Pokémon* out of their *Pokeballs* if you catch him. So if you see *Pikachu* appear on the screen you must not press the space bar. Remember *Pikachu* will let all of your *Pokémon* escape so don't catch him, try not to press the space bar when you see him.'

Participants completed a 70-second practice session for both tasks . All participants demonstrated that they were able to perform the motor controls required. After successful completion of the practice session each participant was left to do the task for 14 minutes.

The experimenter explained that she would be video recording the child's game play and would be sitting quietly at the back of the room if the child needed her.

6.2.7 Coding

Performance was measured first in terms of the number of commission errors made on the two computerised tasks. The CPT II (and the modified *Pokémon* version) provided a measure of commission errors, the number of times the child responded inappropriately by pressing the spacebar when the target stimulus appeared. Commission errors are used as an index of impulsive responding (Barkley, 1996b; Conners, 1994; Corkum & Siegel, 1993; Losier *et al.*, 1996; Shaw & Giambra, 1993). Omission errors, when the child omits to press the spacebar in response to a letter, are said to reflect either failure to attend or slowness in responding to a letter (Conners, 1994). These were recorded but due to a computer error were lost and therefore not used in the analyses.

Performance in terms of activity displayed while engaging with the computerised tasks was coded and recorded by the experimenter from an unobtrusive location at the back of the room and was video recorded to facilitate coding by an independent observer. The experimenter recorded the participant's gross motor behaviour using a 10-second interval recording system adapted from the coding system used by Handen *et al.* (1998). The participant was recorded as being 'on-task' for any given 10-second interval providing off-task behaviour occurred for no more than three consecutive seconds. As soon as a participant spent more than three consecutive seconds attending to or engaging with something else (rated as distracted behaviour, touching an object in the room, fidgeting or out of seat behaviour) their behaviour for that given ten seconds was recorded as 'off-task'. Inter-rater reliability on a sample of just over ten per cent of the observations was assessed using Cohen's Kappa (Cohen, 1960). A value of $k = 0.99$ was observed.

6.3 Results

An alpha level of $p=.05$ was selected for all statistical tests in this thesis.

6.3.1 Performance data: Errors

Mean impulsive (commission) errors and standard deviations (SD) for both ADHD and TD participants on the CPT II and *Pokémon* tasks are presented in Table 5:

Table 5. *Mean commission errors produced by ADHD and TD participants on the CPT II and Pokémon computerised tasks*

	CPT II (SD)		<i>Pokémon</i> (SD)	
ADHD	30.4	(5.0)	24.3	(5.3)
TD	23.6	(8.1)	23.3	(8.6)

Examination of these mean scores shows ADHD participants produced fewer commission errors on the *Pokémon* task compared to the CPT II. TD participants also produced fewer errors on the *Pokémon* task, however not to the same extent. In addition, the number of errors produced by ADHD participants is much closer to that produced by TD participants on the *Pokémon* task.

In order to compare the errors made by children with ADHD and TD children on two computerised tasks a two way mixed ANCOVA, with Ravens's scores added as a covariate, was conducted on the data. This revealed a statistically significant main effect of group ($F(1,29) = 4.26; p=0.048$), but not of task ($F(1,29) = 1.46; p=0.24$, observed power = 0.22). A significant interaction effect was also found ($F(1,29) = 5.01; p=0.032$). It is important to note the relatively low level of observed statistical power of the analysis concerning the main effect of task. This reflects the limited number of participants, it is possible that with a greater numbers of participants a significant difference across tasks may have been observed.

In order to explore the interaction effect and to test the prediction that the children with ADHD would show fewer commission errors on a game version of the CPT II than on the standard CPT II, planned comparisons using one way ANOVAs were conducted on the error rates produced by both groups. These revealed that participants with ADHD

produced significantly more errors on the CPT II than on the *Pokémon* version ($F(1,15) = 15.67; p=0.05$).

In contrast, mean errors produced by the TD group on these two games were not significantly different; ($F(1,15) = 0.009; p=0.93$). This pattern of results suggested that participants with ADHD showed a level of performance enhancement on *Pokémon* that was not observed among TD participants.

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANOVA was conducted on the data produced by ADHD participants. Analysis using the presence of a co-morbid disorder as an additional between participant independent variable revealed no statistically significant interaction between co-morbid status and performance on these two tasks ($F(1,14) = 1.60; p=0.227$).

6.3.2 Performance data: Observations

Observations were made of on-task and off-task (distracted, fidgeting, touching other objects in the room and out of seat) behaviour. These measures were mutually exclusive. The mean number of 10-second intervals spent by the ADHD and TD participants engaging in on-task behaviour whilst completing the two computerised tasks and two computer games are shown in Table 6.

Each task was presented for a total of 14 minutes, consisting of 84 ten-second intervals. All scores presented are therefore out of a maximum possible of 84. The higher the score the more on-task the participants.

Table 6. *Mean number of 10-second intervals spent engaging in on-task behaviour for the ADHD and TD participants whilst playing the CPT II and Pokémon task.*

	ADHD (SD)	TD (SD)
CPT II	44.87 (21.6)	71.31 (13.4)
<i>Pokémon</i>	53.88 (22.8)	70.69 (15.0)

Examination of these mean scores shows that while participants with ADHD exhibited more on-task activity on the *Pokémon* Task, TD participants in contrast exhibited more on-task activity on the CPT II.

In order to examine performance in terms of the amount of on-task activity participants exhibited whilst engaging with the two tasks a mixed ANCOVA was conducted on the data using Ravens's scores as a covariate. This revealed a significant main effect for group ($F(1,29) = 13.68; p=0.001$) but no significant effect of task ($F(1,29) = 1.61; p=0.30$, observed power = 0.18) and no significant interaction between group and game ($F(1,29) = 3.43; p=0.07$, observed power = 0.43).

Despite the non significant interaction, in order to specifically test the prediction that participants with ADHD would show a performance enhancement in terms of less distracted and more on-task activity when playing the more game like computerised task than on the CPT II planned comparisons were conducted on the on-task data. As predicted this showed a significant difference between the amounts of on-task behaviour exhibited by participants with ADHD on the two tasks, with more time being spent on-task on the *Pokémon* Task than on the CPT II ($t(15) = -1.82; p=.044$).

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANOVA was conducted on the data produced by ADHD participants. Analysis did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on the tasks ($F(1,14) = 0.24; p=0.631$).

6.4 Conclusions and Discussion

6.4.1 Summary of Results

The first aim of the study was to compare performance in terms of error making of TD children and children with ADHD on two computerised tasks. As predicted, examination of the mean commission errors produced by TD participants showed no significant

difference on performance across the two tasks. In contrast participants with ADHD showed a significant reduction in impulsive responding on the *Pokémon* task.

Participants with ADHD produced significantly more errors when completing the CPT II. This pattern of responses corresponded to that suggested by the anecdotal reports described earlier and the parental responses obtained in Study 1. As predicted, error making of children with ADHD significantly reduced on the more 'game like' task and was equivalent to that of TD children. These results provide some support for the hypothesis that performance for children with ADHD is enhanced by computer games in a way that it is not for typically developing children.

It is important to note the differences in the performance of TD participants and participants with ADHD on the CPT II. This supported claims that children with ADHD show specific problems of impulsive responding on standardised measures such as the CPT II. In contrast TD children did not exhibit the same difficulties. Furthermore, this finding supported claims that there is something important about the more game like presentation that appeared to facilitate the performance of the children with ADHD. Crucially this improvement was not replicated with TD participants, suggesting that the effect was specific to children with ADHD, and did not result from universally applicable appeal and effects of computer games. There appeared to be something specific about the context of the task, when framed as more of a 'game', that impacted on the performance of the children with ADHD.

In terms of performance as indicated by activity displayed by children with ADHD while engaging with the two computerised tasks, significant differences between groups in the number of intervals spent engaging in on-task behaviour were observed. This finding again corresponded to parental reports presented in Study 1.

In line with the lack of difference between error making on the two computerised tasks, TD participants spent an almost equivalent number of intervals on-task when engaged

with the CPT II and *Pokémon* task. In summary, the findings of this study provided further support for the hypothesis that children with ADHD show greater evidence of enhanced performance when playing computer games than when they are carrying out experimental measures of cognition.

Despite the poorer performance of children with ADHD on the CPT II, participants with ADHD produced significantly fewer errors on the more game like *Pokémon* task. This raised questions about the nature of the task or contextual demands and how these might interact with participants' performance. If performance is context dependent then questions can be raised about the ability of specifically designed measures, such as the CPT II, to accurately reflect a participant's full potential and competence. The findings of this study thus raise further questions concerning the generalisability of findings and validity of such measures in terms of understanding issues such as the nature of inhibition and its relationship with contextual factors.

6.4.2 Conclusion

To summarise, the findings of this study indicated a need for the features of the more 'game like' *Pokémon* task and the game playing context, to be investigated in greater detail. Differences were observed in the way that participants with ADHD performed on the CPT II and on the *Pokémon* task in comparison to TD participants. It was the *Pokémon* task that highlighted the similarities in performance and on-task activity of ADHD and TD participants. A more detailed and specific examination of some of the features of the *Pokémon* version of the CPT II and their relationship with performance was therefore conducted in study 4.

The findings of this study highlighted the importance in distinguishing between performance and competence and suggested that traditional EF research may have revealed more about the nature of performance in restricted contexts and little about 'real world' competence.

The findings of Studies 1, 2 and 3 suggest that the performance of individuals with ADHD is enhanced when playing computer games.

This may be a competence that exists across many settings but due to methodological constraints has not been revealed in research to date, or it may be a competence facilitated by features specific to the computer game playing setting.

Chapter 7

Effects of narrative and reward incentive, character and colour in computerized tasks on performance of children with ADHD and typically developing children.

Introduction

The previous study examined the performance of TD children and children with ADHD on two computerised tasks. Results of Study 3 raised questions about aspects of the *Pokémon* version of the CPT II that were critical in improving performance, reducing commission errors and increasing on-task behaviour. There are a number of differences between the CPT II and the *Pokémon* task. The *Pokémon* task used characters instead of letters, a more salient and relevant goal and a narrative that set the scene and gave the reason for the task. These features were identified as possible influencing factors on error making and on-task activity. The overall aim of the two studies reported in this chapter was to examine these features of the *Pokémon* task to identify their effects on performance. Taking into consideration Donchin's (1995) view that in order to use computer games as a research tool it is necessary to manipulate and control their parameters carefully, and in view of the observed effect in Study 3, it was decided to continue with relatively controlled 'game like' task manipulations, such as the *Pokémon* task. Study 4 therefore examined the effect of providing a salient goal, in the form of a point system, a narrative outlining the aim of the task, and the combined effects of a point system and narrative on performance and activity exhibited whilst engaging with a computerised 'game like' task. Study 5 examined the effect of using cartoon characters rather than letters as stimuli. In addition, Study 5 examined the combined effects of using cartoon characters with the points system used in Study 4.

Study 4. Effect of narrative and reward incentive on performance of children with ADHD and typically developing children on 4 computerised tasks.

7.1 Introduction

The first aim of this study was to examine the effect of providing a more salient goal on performance and activity exhibited whilst engaging with a computerised 'game like' task. According to the literature on computer games and motivation the addition of a salient goal is considered of particular importance. Malone (1981) concluded that the most important factor determining a computer game's popularity was whether or not it had a specific goal to be achieved by the player. Malone (1981) reported that computer games players preferred games that gave scores. In order to examine the effect of a salient goal a version of the CPT II was therefore designed with the addition of a points scoring system. The participant's response to letters and target X's was reflected in the points awarded visually on screen. This task was referred to as the Points Task.

The second aim of the study was to examine the effect of the addition of a narrative. Ju and Wagner (1997) reported that this is one of the most important factors that makes a game fun. In order to do this a version of the CPT II was presented to participants after they had been told a story that set the scene and gave a reason for responding to letters and target X's. This task was referred to as the Story Task.

The third aim of the study was to examine the combined effects of the salient goal and the narrative. In order to achieve this an additional condition was added to the experiment. This condition involved both a narrative and points. In order to achieve this condition the Points Task was presented to participants with a repetition of the narrative used in the Story Task. This was referred to as the Points with Story Task.

Performance in terms of commission errors on each of these tasks was compared to that produced on a shortened version of the *Conners' CPT II* simply referred to as the Short CPT II. Omission errors were examined in order to compare level of responding across the tasks.

In contrast to the effect on the performance of typically developing children, it was expected that any one of these aspects, the addition of a salient goal, or the addition of a story, or these aspects in combination, would result in enhanced performance of children with ADHD. It was predicted that these improvements would be consistent with the improvements seen in performance on the *Pokémon* task in Study 2.

It was therefore predicted that:

- there would be no difference in the performance and activity of typically developing children across tasks;

but that participants with ADHD would:

- produce fewer errors on the Points Task, Story Task and the Points with Story Task than on the shortened CPT II,
- display more on-task activity when completing the Points Task, Story Task and the Points with Story Task than on the shortened CPT II.

7.2 Method

7.2.1 Design

The study used a mixed design. The dependent variable tested was performance in terms of commission errors, and on-task activity. Four modifications were made to the *Conners' CPT II*. The order of presenting the tasks was not counterbalanced due to the nature of the information presented in the tasks. It was possible that carry over effects could have disrupted performance if the order of presentation of these tasks was not set. This could have been addressed by different groups of both children with ADHD and

typically developing children completing each task, however due to the practicalities of additional participant recruitment for the ADHD group, and the desire to use a repeated measures matched pairs design the issue of order effects was taken into consideration during examination of the results.

7.2.2 Participants

Participants with ADHD were recruited from support groups and TD participants from after school clubs and playschemes on the basis that they indicated an interest in playing computer and console games. Sixteen children with ADHD and 16 TD children participated and were matched on level of experience with computers, and on their Raven's Progressive Matrices Score as a measure of non verbal IQ. Both the ADHD and TD groups contained one female and 15 male participants. None of the participants had taken part in Study 3. The age of participants with ADHD ranged from 4 years 1 month to 12 years 8 months, mean age 8 years and 8 months (SD 2.5). The age of TD participants ranged from 4 years 0 months to 14 years and 2 months, mean age 7 years and 6 months.

Participants were recruited in the same way and according to the same selection criteria as Study 3. Once again, computer experience was assessed in the same way as for Study 3. A total of 7 participants with ADHD had disorders which co-occur with ADHD, including Asperger's Syndrome (1), Autistic Spectrum Behaviours (1), Dyspraxia (2), Oppositional Defiance Disorder (3) and Learning Disabilities (2). These were taken into account during statistical analyses. None of the TD children had any known disability. Table 7 summarises the characteristics of participants.

Table 7.

Characteristics of ADHD and TD participants in terms of Age, Raven's Progressive Matrices Score and General level of experience on computers.

	Age	Mean Ravens' Progressive (SD) Matrices Score		General Level of Experience with Computer Games
ADHD	8.8 years (3.43)	50 th per centile	(6.89)	Experienced
TD	7.6 years (2.69)	50 th per centile	(8.05)	Experienced

7.2.3 Tasks

The method employed was a replication of that used in the previous study using modified tasks. The CPT II was modified to produce four new tasks. Each task was designed to be isomorphic in relation to the CPT II as used in the previous study.

The Short CPT II

The original CPT II lasts for a total duration of 14 minutes. However, for the purpose of this study it was decided that tasks needed to be shorter in duration in order to avoid fatigue and boredom. Performance on the full version of the CPT II gained in the previous study was examined to see where it reached a plateau. This informed development of a shortened version of the CPT II. Block by block examination of performance on the CPT II in Study 3 revealed that differences in performance of ADHD participants emerged after the first block of letter presentation. The CPT II was therefore modified to a reduced duration of 4 minutes 30 seconds (sufficient to allow 2 blocks of letter presentation). In addition, data collected in Study 3 allowed examination of performance across inter stimulus intervals (ISI's). No significant differences in performance across ISI's were seen. This shortened CPT II therefore used an ISI of 2 seconds. A total of 12 target Xs were included. Letters continued to be displayed for a total of 250 milliseconds. A comparison of average scores for the full CPT II from study 3 and scores gained from the short CPT II in this study were planned to test equivalence.

The Points Task

This task was a copy of the modified CPT II with the addition of a points scoring system, presented in the top right hand corner of the screen. Participants received 10 points for every letter responded to, apart from the target letter X. A deduction of 10 points was made when the participant incorrectly responded to the X.

The Story Task

Visually this was an exact duplicate of the first. However presentation was accompanied by a brief story, which emphasised the reason for not responding to the X. The story is detailed in the procedure section (7.2.4).

The Points with Story Task

This was visually the same as the Points Task. In addition, participants were told the story used in the Story Task. Participants were reminded of the rules of the scoring system and were told that this would reflect their success at achieving the goal described in the story.

7.2.4 Procedure

All children were tested in their homes. The setting was informal and naturalistic with distracting objects, such as a television and toys, in the room. Participants with ADHD again abstained from taking medication four hours prior to testing. They continued to take their medication as soon as testing finished. As for Study 3 all participants with ADHD who had been prescribed medication were taking fast acting medications that are effective for approximately 4 hours, after which they require another dose. To abstain from medication for the duration required for testing therefore had a minimal impact on long term treatment and could be resolved as soon as testing had finished. Again this was confirmed and approved by participants' consultant paediatricians and psychiatrists and only participants whose parents also consented took part in the study. Nevertheless, it must be noted that residual methylphenidate may have affected the performance of children with ADHD.

Participants were asked if they would like to play a few games on the laptop. Positive responses were followed by a quick discussion about the child's favourite games. During this discussion participants were asked to rate their level of computer game playing experience (reported in Table 7). The experimenter also asked whether the child would object to being video recorded. The behaviours of those who raised no objections were video recorded. As a result all but one participant were recorded.

Participants were presented with the four computerised tasks. It was decided to present the tasks in a fixed order so that information gained through previous exposures, particularly the narrative which provided the reason for the task would not hinder or interfere with performance on the next task. In other words, if tasks with the narrative were presented first it was possible that the participant would recall this narrative in subsequent tasks and would infer that this applied to all subsequent tasks, even if not prompted to do so by the researcher. All participants therefore completed the Short CPT II, followed by the Points Task, the Story Task, and finally the Points with Story Task. For each task participants were given clear instructions and the experimenter demonstrated what was required.

For the first task the experimenter explained 'The computer will show lots of letters on the screen one at a time. You will need to press the spacebar for all of the letters that you see except for the letter X, the one that looks like this.... Please press the spacebar as quickly but also as accurately as possible. Remember please press the spacebar for any letter you see apart from the X. First we will have a quick practice session and then I will let you play the whole game. The game will last for 4 and a half minutes. When you click the OK button, the session will start'.

For the second task the experimenter emphasised the fact that the second game was just the same as the first, the child was told that they again needed to press the spacebar for all of the letters that came up on the screen apart from the letter X. The experimenter then

introduced the scoring system. The child was told that 10 points would be given every time they pressed the spacebar when they saw a letter. In addition, they were told that 10 points would be taken off their score if they pressed the spacebar when they saw the X.

For the third task the experimenter told a brief story and gave a reason for not responding to the X. The experimenter explained 'The computer is hungry. Its favourite food is alphabet soup. We can help the computer to make its alphabet soup by catching the letters when they appear on the screen. The idea of the game is to catch as many letters as you can. You will see a letter appear on the screen and in order to catch it you must press the space bar as quickly as possible, just like you did before. All the letters you catch will be kept inside a special box inside the computer. When we have finished the game the computer can open the box and use the letters to make alphabet soup. But there is one problem. The letter X is feeling a bit naughty today. The letter X has stolen the key to the box and will free all of your letters out of their box if you catch him. So if you see the letter X appear on the screen you must not press the space bar. Remember the letter X will let all of your letters escape so don't catch the X, try not to press the space bar when you see the X.'

For the fourth task each child was told that 'this time in order to help you collect as many letters as possible for the computer's alphabet soup you will also see a score in the top left corner of the screen, just like before. The higher the score the greater the number of letters you have collected. But just to remind you not to catch the naughty letter X a total of 10 points will be taken away from your score if you press the spacebar when you see the X'.

After receiving instructions participants completed a 70-second practice session of the task. After successful completion of the practice session each participant was left to complete the task. The experimenter explained that she would be sitting quietly at the back of the room if the child needed her. After completion of each task the experimenter

thanked the child for their participation and asked whether they would like to play another game. All participants responded positively. On completion of the fourth task participants were complimented on their performance and thanked for their participation.

7.2.5 Coding

The computer programme recorded commission and omission errors for each task. An error was recorded each time the child responded inappropriately by pressing the spacebar when the X appeared.

Activity exhibited whilst completing the computerised tasks was recorded by the experimenter from an unobtrusive location at the back of the room. For those participants who consented activity was also recorded via a digital video camera. This camera was placed in front of the monitor and in a position to facilitate recording behaviour.

As for the previous study gross motor behaviour was recorded and coded using a 10-second interval recording system adapted from the measure used by Handen *et al.* (1998). Activity during any one 10-second interval was therefore coded as being on-task or off-task. Categorisation was mutually exclusive and exhaustive. Previous inter-observer comparisons made using this measure (Study 3) were assessed using Cohen's Kappa and produced a K value of 0.99, confirming the reliability of the measure. Inter-observer comparisons made for the present study supported this finding, producing a κ value of 0.96.

7.3 Results

7.3.1 Performance data: Errors

In order to control for potential differences in overall levels of responding of both groups of participants on the tasks omission errors were included in subsequent statistical analyses as a covariate in order to ensure that any differences in commission error making were not a reflection of differences in overall levels of responding. In order to examine performance the commission errors produced by both groups of participants

were examined. The mean commission errors and standard deviations (SD) produced by participants with ADHD and typically developing participants on the four tasks are presented in Table 8.

Table 8.

Mean commission errors produced on the Short CPT II, the Points Task, the Story Task and the Points with Story Task.

	CPT II (SD)		Points (SD) Task		Story (SD) Task		Points & (SD) Story Task	
ADHD	9.99	(1.59)	10.16	(1.44)	9.08	(1.94)	10.34	(1.20)
TD	7.56	(2.16)	7.19	(1.72)	8.00	(1.21)	7.69	(1.74)

Examination of these mean scores shows that participants with ADHD produced fewest errors on the Story Task and the greatest number of errors on the Points with Story Task. TD participants produced the fewest errors on the Points Task and the greatest on the Story Task.

In order to compare the performance of the two groups of children on the four computerised tasks a two way mixed ANCOVA (2 groups by 4 tasks) was conducted on the commission errors with Ravens' scores and omission errors as covariates. This revealed a statistically significant main effect of group ($F(1,25) = 7.87; p=0.01$). There was no main effect of task ($F(3,75) = 0.26; p=0.86$). The observed power of this test was 0.10 and this non-significant effect must be considered in the light of this. A significant interaction between group and task was not found ($F(3,75) = 1.38; p=0.26$) the observed power of this test was 0.35 and again this non significant effect must be considered in the light of this.

It was predicted that participants with ADHD would produce fewer errors on the Points Task, Story Task and the Points with Story Task than on the Short CPT II. However, contrary to prediction, examination of the raw data (Table 8) showed greater error

making on the Points Task and Points with Story Task compared to the Short CPT II. These planned comparisons were therefore not made. Despite these results the planned comparison conducted on the data produced on the Story Task and Short CPT II was made as mean scores showed a reduction in error making on the Story Task compared to the CPT II. However, a one-way ANCOVA, with Ravens' scores and omission errors added as covariates, revealed that this difference in error rates was not statistically significant ($F(1,12) = 0.12$; $p=0.73$, observed power = 0.06).

In order to examine any effects of co-occurring disorder a mixed ANCOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable revealed no statistically significant interaction between status (one or more co-morbid disorder versus no co-morbidity) and performance on the four tasks ($F(3,42) = 0.238$; $p= 0.87$, observed power = 0.09).

7.3.2 Performance data: Observations

Observations were made of on-task behaviour and off-task behaviour as for Study 3. Each task was presented for a total of 4.5 minutes, consisting of 27 10-second intervals. All scores presented are therefore out of a maximum possible score of 27. These are summarised in Table 9.

Table 9.

Number of 10-second intervals spent on-task while completing the Short CPT II, the Points Task, the Story Task, and the Points with Story Task.

	ADHD (SD)	TD (SD)
Short CPT II	11.88 (3.40)	21.13 (2.34)
Points Task	20.44 (5.40)	20.19 (2.40)
Story Task	13.63 (5.71)	22.06 (1.24)
Points with Story Task	20.44 (3.60)	21.75 (2.18)

Examination of the data presented in Table 9 revealed a wide variation in the amounts of time spent on-task displayed by the participants with ADHD across the tasks. In contrast there was little difference in the amounts of time spent on-task across tasks by TD participants. In summary, participants with ADHD spent the greatest number of 10-second intervals engaging in on-task behaviour when completing both the Points Task and the Points with Story Task, followed by the Story Task. They spent the lowest number of 10-second intervals on-task when completing the Short CPT II. TD participants spent the greatest number of intervals on-task for the Story task, and the fewest intervals on-task for the Points Task, but these differences were very small.

A two way mixed ANCOVA, using Ravens's score as a covariate, conducted on the data revealed significant main effects for group ($F(1,29) = 32.51; p < 0.001$) and task ($F(3,87) = 4.28; p < 0.01$) and a significant interaction between group and task ($F(3,87) = 27.61; p < 0.001$). The nature of this interaction can be seen in Figure 8

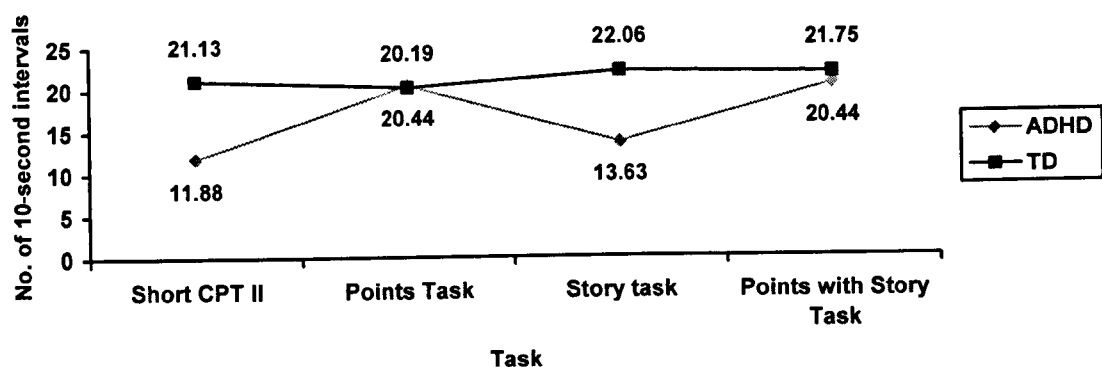


Figure 8. On-task activity exhibited by participants with ADHD and TD participants on the Short CPT II, Points Task, Story Task and Points with Story Task.

In order to examine the three aims of the study and to test the prediction that participants with ADHD would display more on-task activity when completing the Points Task, Story

Task and the Points with Story Task than on the Short CPT II planned comparisons were conducted on the on-task data. As predicted these showed a significant difference between the amounts of on-task behaviour exhibited by the participants with ADHD on the Short CPT II compared to the Points Task ($F(1,14) = 4.559; p < 0.05$), and the Short CPT II compared to the Points with Story Task ($F(1,14) = 8.217; p < 0.01$). However, contrary to prediction, on-task behaviour exhibited by participants on the Short CPT II compared to the Story Task was not significantly different ($F(1,14) = 0.483; p = 0.50$, observed power 0.09).

In contrast, and as predicted, a one way ANOVA conducted on the on-task data produced by TD participants did not reveal a significant difference between on-task behaviour across the four tasks ($F(3,45) = 4.17; p = 0.011$, observed power 0.82), further comparisons across tasks were therefore not made.

In order to give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANCOVA was conducted on the data. Analysis did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on the tasks ($F(3,42) = 0.60; p = 0.618$).

7.4 Discussion

7.4.1 Findings and Implications

Participants with ADHD performed significantly differently on the four computerised tasks than typically developing participants. Mean commission errors produced by typically developing participants did not differ greatly on the three computerised tasks compared to the CPT II. In contrast, the commission errors produced by participants with ADHD were more variable, and mean scores showed a reduction in the errors produced on the Story Task and those produced on the short CPT II. However, analyses revealed that this difference was not statistically significant. Contrary to prediction, the addition of the story did not appear to enhance the performance of participants with ADHD to the

same degree that it appeared to on the *Pokémon* task in the previous study, which suggested that this feature had a positive effect on the ability of participants with ADHD to inhibit an inappropriate response. In Chapter 1 it was hypothesised that the addition of the story used in the *Pokémon* Task may have increased participants' interest and thus motivation to succeed and may have made the task more relevant and meaningful. However, despite some decrease in error making, story used in the present study did not appear to impact on performance to a significant level. In short the changes to the contextual characteristics encompassed in the *Pokémon* Task seemed to enable children with ADHD to overcome some of their difficulties in inhibiting an ongoing response, however, this was not replicated in the present study.

Furthermore, also contrary to prediction, participants with ADHD did not produce fewer commission errors on the Points Task and the Points with Story Task than on the shortened CPT II. Unlike the story, the goal of collecting points was not a feature of the original *Pokémon* task. The points system was added in order to try to examine the effects of an intrinsically motivating goal, a theorised feature of the *Pokémon* task, as discussed by Malone (1981). However, it is important to remember that Malone's claims were based upon the opinions expressed by typically developing children. There is currently no equivalent research that has focused on children with ADHD. It is therefore possible that the points system employed did not provide a sufficiently salient goal for this group of participants. To also be considered is the possibility that the costs and rewards involved in the points system did not provide sufficient incentive to motivate the participants and to affect performance in the way predicted.

Alternatively, it is also possible the interaction between contextual features and executive performance is more complex than first assumed. Observations of gross motor activity suggested that this may have been the case. There was a strikingly counter intuitive finding concerning the pattern of error making and on-task activity. Despite their poorer

performance on the Points Task and Points with Story Task participants with ADHD spent the most, and significantly more, intervals engaging in on-task behaviour when completing these tasks compared to the shortened CPT II. In contrast, participants produced marginally (but not significantly) fewer errors on the Story Task than on the CPT II, but did not display significantly more on-task activity for this task.

This suggested that there may not be a linear relationship between these different executive processes, and that improvements in one type of processing do not necessarily coincide with improvements in other areas of processing. This might have implications for some of the theories of ADHD outlined in Chapter 2. In particular this finding may have particular relevance for core deficit theorists, such as Quay (1988; 1997) and Barkley (1997a; 1997b) who hypothesised a linear relationship between attention and ‘secondary’ executive processes and ‘primary’ inhibitory processing. These implications are discussed in greater detail in Chapter 10.

The results also pointed to a need to consider the processing demands of the different contexts and the interaction with executive performance. The Points Task involved more visual processing during task presentation. The Story Task involved more auditory processing prior to the task. The presentation of further visual stimuli may have distracted the participants from the aim of the task as set out in the task instructions. This factor is explored in greater detail later in Study 6, and theoretical implications are explored further in Chapter 10.

7.4.2 Methodological Evaluation

It is important to remember that this investigation used a small sample of participants with ADHD, only one of whom was female. Identification of co-morbid disorders was also lower than one would expect for an ADHD population. Participants were selected from ADHD support groups. As a result the degree to which these participants can be said to be representative of a wider ADHD population must be questioned.

For the purpose of this repeated measures investigation it was also necessary to order task presentations. As a result one cannot completely rule out practice effects, although on examination of performance data this seems unlikely. For example the task that was presented last was performed worse. In addition it is possible that fatigue and boredom may have affected the results, although examination of on-task behaviour suggests that this is also unlikely. The task presented last was attended to best.

As discussed in the methods section the CPT II was shortened based on the need to avoid fatigue and boredom. In order to investigate whether shortening the CPT II had any effect on performance scores on the longer version of the CPT II gained in Study 3 were compared to scores produced on the Short CPT II in this study to examine equivalence.

7.4.3 Summary

In summary, the results suggest that in contrast to the performance of TD children across tasks, the performance of children with ADHD appeared to be influenced by changes in task characteristics and context. It also emerged that there is a need to distinguish between different types of inhibitory processing and possible processing pathways. A possible dissociation between performance in terms of commission errors and performance in terms of omission errors and attentive behaviour emerged. The task feature of a points system was found to be important in increasing on-task focus and activity, but did not aid ability to inhibit an ongoing response. The role of motivation and its interaction with a deficit of inhibition in ADHD appeared to be of particular importance.

To conclude, with reference to the previous results from Study 3, the findings suggest that task characteristics associated with the addition of a story could not account for the differences in performance of children with ADHD observed between the *Pokémon* task and the CPT II. When scores from the Story Task were multiplied to account for the longer duration of the *Pokémon* task in Study 3 mean error rates were marginally higher,

and on-task activity ratings marginally lower for the Story Task than the *Pokémon* Task respectively.

In addition, the points system had a different and unpredicted effect. Neither of these task characteristics appeared to result in enhancements consistent with the simultaneous improvements in both error making and on-task activity seen on the *Pokémon* Task.

Alternative features of the *Pokémon* Task may account for these improvements. One such feature is the substitution of target item letters for colourful, familiar cartoon characters.

This is a distinct visual difference between the original CPT II and the *Pokémon* Task.

Examination of this task characteristic was therefore proposed for investigation in Study 5.

In addition the findings highlighted an important interaction between the points system and the two measures of performance of children with ADHD. Study of the interaction between the points system and the suggested manipulation of target characteristics (colour and character) was also proposed for Study 5.

Study 5. Effect of character, colour and reward incentive on performance of children with ADHD on 5 computerised tasks.

7.5 Introduction

The previous study (Study 4) examined the performance of children with ADHD on four computerised tasks. Findings suggested that the addition of a points system had a different and unpredicted effect. Although the participants with ADHD displayed more on-task activity when points were added their performance did not improve.

To summarise, investigation of the two features in the previous investigation did not produce results entirely consistent with the finding of simultaneous improvement in performance and on-task behaviours seen for the *Pokémon* task in Study 3. There are

additional features of the *Pokémon* task that were not examined in Study 3 that merit attention. One such feature was the substitution of letters for colourful and familiar cartoon characters. The first aim of the present investigation was to examine the effect of replacing letters with cartoon characters, both in black and white and in colour. In order to do this two new versions of the task were designed. One of these substituted letters for black and white *Simpsons* characters, referred to as the Black and White *Simpsons* Task, the other substituted letters with coloured *Simpsons* characters, referred to as the Coloured *Simpsons* Task.

In addition, the previous investigation highlighted an interesting interaction between the points system and performance in terms of error making and on-task activity. The second aim of Study 5 was to examine the effect of the addition of the points system to the black and white and coloured cartoon character versions of the task. Two additional tasks were therefore designed; the Black and White Points *Simpsons* Task, and the Coloured Points *Simpsons* Task. Since both the TD participants and those with ADHD who took part in Study 4 also took part in Study 5 it was possible to compare their performance on each of these four new tasks to their performance on the short CPT II in Study 4.

Following the previous investigation it was hypothesised that while TD participants would not perform differently across tasks, children with ADHD would perform better on tasks that involved the aspects of colour and character, consistent with the *Pokémon* task. It was therefore predicted that:

- there would be no difference in the performance and activity of TD participants across tasks.

But that participants with ADHD would:

- produce fewer errors on the Coloured *Simpsons* Task and the Black and White *Simpsons* Task compared to the Short CPT II;

- would exhibit more on-task activity on the Coloured *Simpsons* Task and the Black and White *Simpsons* Task compared to the Short CPT II.

However, consistent with findings from Study 4 it was also hypothesised that the addition of the points system to both black and white and colour tasks would counteract the effects of colour and character, but enhance on-task behaviour compared to the Short CPT II.

Thus the predictions were that participants with ADHD would:

- produce greater errors on both the Coloured Points *Simpsons* Task and the Black and White Points *Simpsons* Task than on the Short CPT II; but
- produce more on-task activity on both the Coloured Points *Simpsons* Task and the Black and White Points *Simpsons* Task than on the CPT II.

7.6 Method

7.6.1 Design

The study had a similar design to that of Study 4. The performance of participants with ADHD and TD participants was compared across tasks. The dependent variable tested was again performance in terms of errors of commission and on-task activity. For this study there were five modifications of the Conners' CPT II. The presentation of tasks was counterbalanced.

7.6.2 Participants

Participants with ADHD and TD participants who had taken part in Study 3 were approached. All 16 children from each group agreed to participate in this study. Of these children one participant from each group was female, the rest male. The age of participants with ADHD ranged from 4 years 1 month to 12 years 8 months, mean age 8 years and 8 months (SD 2.5). TD participants were between 4 years 0 months and 14 years 2 months, mean age 7 years and 6 months. Section 7.2.2 gives relevant participant details.

7.6.3 The Tasks

Each task was presented in the same way as the Short CPT II in Study 4. Characters were presented with ISIs of 2 seconds, with a display time of 250 milliseconds, for a total task duration of 4 minutes 30 seconds. A total of 12 target characters, to which participants were required to inhibit responding, were presented.

The Black and White *Simpsons* Task

Simpsons cartoon characters were presented in black and white instead of letters.

Participants were instructed to press the spacebar for all of the characters they saw, apart from the character 'Bart'.

The Coloured *Simpsons* Task

Simpsons cartoon characters were presented in colour instead of letters. As before participants were told to press the spacebar for all characters apart from 'Bart'.

The Black and White Points *Simpsons* Task

As for the Black and White *Simpsons* Task all characters were presented in black and white and participants were instructed to press the spacebar for all characters except 'Bart'. However, for this task points were presented in the top right corner of the screen. Participants were told that they would receive 10 points every time they pressed the spacebar in response to a character, but that every time they pressed the spacebar when they saw 'Bart' 10 points would be taken off their score.

The Coloured Points *Simpsons* Task

As for the Coloured *Simpsons* Task all characters were presented in colour and participants were instructed to press the spacebar every time they saw a character, but to not press the spacebar when they saw 'Bart'. This task also included the Points system, presented in the top right corner of the screen. Participants were again told that they would be given 10 points each time they pressed the spacebar on seeing a *Simpsons*

character, but that 10 points would be taken away if they incorrectly pressed the spacebar on seeing *Bart*.

7.6.4 Procedure

All children were tested in their homes. The setting was informal and naturalistic. In all cases there were distracting objects, such as a television and toys, in the room.

As for Studies 3 and 4 participants again abstained from taking medication 4 hours prior to testing. They continued to take their medication as soon as testing finished.

Participants' parents and consultants had agreed to this arrangement for both this and the previous study.

Participants were re-introduced to the experimenter, were thanked for their help last time and were asked if they would like to play a few more of the games, 'just like before' on the laptop. Participants were then presented with the four new tasks. The experimenter asked whether the child was familiar with the *Simpsons* cartoon characters and in particular 'Bart'. All participants were familiar with the characters. The experimenter asked whether the child would object to being video recorded, the behaviours of those who raised no objections were recorded. None of the children objected and all were therefore recorded.

The presentation of tasks was counterbalanced. For each task the experimenter explained 'The computer will show lots of *Simpsons* characters on the screen, one at a time. You will need to press the spacebar for all of the characters that you see except for *Bart*, do you know what he looks like? He is the boy on the skateboard. Please press the spacebar as quickly but also as accurately as possible. Remember please press the spacebar for everyone you see apart from *Bart*. First we will have a quick practice session and then I will let you play the whole game. The game will last for 4 and a half minutes. When you click the OK button, the session will start'.

As for Study 4, after giving the instructions the experimenter demonstrated what was required. Participants were presented with 70 seconds of the task as a practice session. All participants completed this successfully. Each participant was then left to complete the task. The experimenter explained that they would be sitting quietly at the back of the room if the child needed them.

On completion of each task the experimenter returned to the child and thanked them for their participation. The experimenter asked if they would like to play the next 'game'. All participants responded positively. On completion of the last task participants were complimented on their performance and thanked for their participation.

7.6.5 Coding

The computer program recorded a commission error each time the child responded inappropriately by pressing the spacebar when '*Bart*' appeared. This provided an index of impulsive responding. Omission errors were recorded if the child failed to respond to a stimulus.

Behaviour while completing these computerised tasks was recorded by the experimenter from an unobtrusive location at the back of the room. As in both previous studies the experimenter recorded the participant's on-task and off-task behaviour using a 10-second interval recording system adapted from the measure used by Handen *et al.* (1998). Inter observer ratings were analysed using Cohen's Kappa and produced a *K* value of 0.97.

7.7 Results

7.7.1 Performance data: Errors

In order to control for potential differences in overall levels of responding of both groups of participants on the tasks omission errors were included in subsequent statistical analyses as a covariate in order to check that any differences in commission error making were not a reflection of differences in overall levels of responding. In order to examine performance the commission errors produced by both groups of participants were

examined. The mean commission errors and their standard deviations (SD) produced by participants with ADHD and TD participants on the four tasks in addition to the short CPT II are presented in Table 10.

Table 10.

Mean commission errors produced on the Short CPT II and the four versions of the Simpsons task.

	Short CPT	Black & White	Coloured	Black & White	Coloured
	II	<i>Simpsons</i> Task	<i>Simpsons</i> Task	Points <i>Simpsons</i> Task	Points <i>Simpsons</i> Task
ADHD (SD)	9.99 (1.59)	7.13 (2.10)	6.59 (3.23)	7.42 (3.73)	8.11 (3.59)
TD (SD)	7.56 (2.12)	7.63 (2.60)	7.50 (2.85)	7.31 (2.12)	7.06 (1.57)

Examination of mean scores shows that participants with ADHD produced the most errors on the Short CPT II. The second highest error rate was seen for the Coloured Points *Simpsons* Task, followed by the Black and White Points *Simpsons* Task and the Black and White *Simpsons* Task. The fewest errors were produced on the Coloured *Simpsons* Task. TD participants produced the highest error rate on the Black and White *Simpsons* Task and the fewest errors on the Coloured Points *Simpsons* Task.

A mixed ANCOVA conducted on the data produced by participants with ADHD and TD participants using Ravens’ scores and omission errors as covariates did not reveal a significant main effect of group ($F(1,24) = 0.074$; $p=0.788$, observed power 0.07) However it did reveal a significant main effect of task ($F(4, 96) = 2.89$; $p=0.026$), and a significant interaction between task and group was found ($F(4,96) = 2.93$; $p=0.025$). The nature of this interaction is shown in Figure 9.

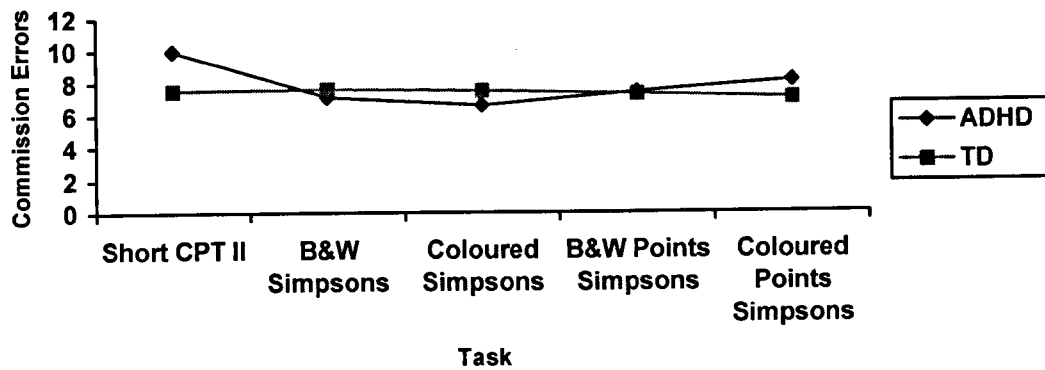


Figure 9. Commission errors produced by participants with ADHD and TD participants on the Short CPT II and four Simpsons Tasks.

As predicted a one way ANCOVA revealed no significant difference in the performance of TD participants across tasks ($F(4,56) = 1.050$; $p=0.390$, observed power .31).

Planned comparisons were conducted in order to test the prediction that participants with ADHD would produce fewer errors on the Coloured *Simpsons* Task and the Black and White *Simpsons* Task compared to the Short CPT II. As predicted these revealed significantly different error rates on the Short CPT II compared to the Black and White *Simpsons* Task ($F(1,12) = 4.595$; $p<.05$) and on the Short CPT II compared to the Coloured *Simpsons* Task ($F(1,12) = 6.101$; $p<.05$).

Further planned comparisons were conducted to test the prediction that participants with ADHD would produce greater errors on both the Coloured Points *Simpsons* Task and the Black and White Points *Simpsons* Task compared to the Short CPT II. However despite the fact that these also revealed a significant difference in error making on the Short CPT II compared to the Black and White Points *Simpsons* Task ($F(1,12) = 4.517$; $p<.05$) and on the Short CPT II compared to the Coloured Points *Simpsons* Task ($F(1,12) = 7.878$; $p<.05$) the difference was not in the direction predicted. Participants produced fewer errors on the two *Simpsons* Points tasks.

In order to give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANCOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and performance on these five tasks ($F(4,52) = 1.452$; $p = 0.230$, observed power = 0.42).

7.7.2 Performance data: Observations

Observations were made of on-task and off-task behaviour. The mean number of 10-second intervals spent engaging in on-task and off-task behaviour whilst completing the five computerised tasks is summarised in Table 11.

Each task was presented for a total of 4.5 minutes, consisting of 27 10-second intervals. All scores presented are therefore out of a maximum possible score of 27.

Table 11.

Number of 10-second intervals spent engaging in on-task activity while completing the Short CPT II, and the four Simpsons Tasks.

	ADHD (SD)	TD (SD)
Short CPT II	11.88 (3.40)	21.13 (2.34)
Black and White <i>Simpsons</i> Task	17.00 (5.62)	20.94 (1.81)
Coloured <i>Simpsons</i> Task	16.56 (4.16)	22.38 (1.96)
Black and White Points <i>Simpsons</i> Task	20.31 (3.44)	22.06 (2.04)
Coloured Points <i>Simpsons</i> Task	18.31 (5.75)	22.50 (1.71)

A mixed ANCOVA conducted on these data, using Ravens's scores as a covariate, revealed a significant effect of group on on-task activity ($F(1,29) = 62.32$; $p < 0.001$). A significant effect of task on performance was not found ($F(4,116) = 1.70$; $p < 0.155$, observed power 0.50). However, a significant interaction between group and task was found ($F(4, 116) = 5.18$; $p < 0.001$). The nature of this interaction can be seen in Figure 10.

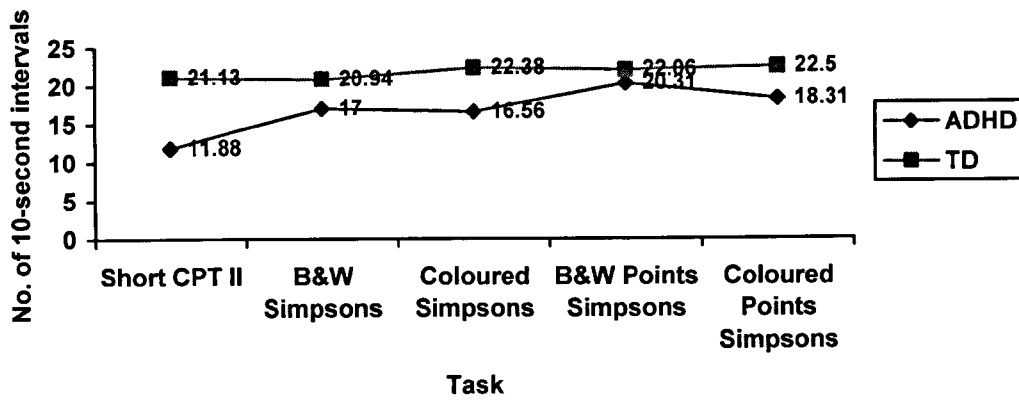


Figure 10. On-task activity exhibited by participants with ADHD and TD participants on the Short CPT II and four Simpsons Tasks.

As predicted a one way ANCOVA conducted on the data produced by TD participants did not reveal a significant difference in on-task activity across the five tasks ($F(4,60) = 1.050$; $p=0.390$, observed power 0.31).

Planned comparisons were conducted in order to test the prediction that participants with ADHD would exhibit a performance enhancement in terms of more on-task activity on the Coloured *Simpsons* Task and the Black and White *Simpsons* Task compared to the Short CPT II. As predicted these revealed significantly less on-task activity on the Short CPT II compared to the Black and white *Simpsons* Task ($F(1,15) = 7.165$; $p < .05$) and the Short CPT II compared to the Coloured *Simpsons* Task ($F(1,15) = 10.517$; $p < .005$). Planned comparisons were also conducted in order to test the prediction that participants with ADHD would exhibit more on-task activity on both the Coloured Points *Simpsons* Task and the Black and White Points *Simpsons* Task than on the Short CPT II. Again, as predicted these revealed significant differences between on-task activity on the Short CPT II compared to the Black and White Points *Simpsons* Task ($F(1,15) = 59.339$; $p < .001$) and the Short CPT II compared to the Coloured Points *Simpsons* Task ($F(1,15) = 11.926$; $p < .005$). These differences were in the direction predicted. Participants produced

more on-task activity for each of the *Simpsons* tasks and significantly less on the Short CPT II.

In order to give an indication of whether co-morbid disorders were having any systematic effects on the data, mixed ANOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on these five tasks ($F(4,56) = 0.863; p = 0.492$).

7.8 Study 5 Conclusions and Discussion

7.8.1 Summary of Findings

Once again changes in performance of participants with ADHD appeared to occur across contexts and with specific manipulations to task features and framing. In contrast, and as predicted, TD participants did not perform differently across tasks. Participants with ADHD showed significant improvements in performance on tasks that involved the elements of colour and character. This was consistent with findings of the *Pokémon* task. The greatest reduction in commission error making of participants with ADHD was seen on the Coloured *Simpsons* Task. Contrary to prediction and previous findings, the addition of a points system did not appear to impair their commission error making compared to performance on the Short CPT II. Reductions in error making were seen for participants with ADHD on both tasks involving a points system relative to the Short CPT II. This was regardless of colour or black and white character presentation. However, it must be noted that the addition of points did appear to impair their performance relative to error making on the *Simpsons* tasks without points.

Significant improvements in performance in terms of on-task behaviour were seen for participants with ADHD on all tasks compared to the Short CPT II. As predicted the addition of characters resulted in increased on-task attention for this group of participants. Examination of the mean number of 10-second intervals spent on-task indicated that the

greatest improvements in attentive performance were observed for tasks that included a points system and that the addition of colour did not appear to affect performance in a consistent manner.

The findings of this study indicate that all manipulations of character and points facilitated improvements in performance for participants with ADHD both of error making and on-task activity compared to the Short CPT II. The addition of character appeared to be the most influential factor affecting the ADHD participants' ability to inhibit an inappropriate response. The addition of familiar and popular *Simpsons* characters may have increased the children's interest and made the task more relevant and meaningful, resulting in increased effort, arousal and use of processing resources. This factor could also account for the findings of the *Pokémon* task.

The addition of the points system had a particularly interesting effect on the behaviour of participants with ADHD. This was consistent with findings from the previous study. The points system was added in order to try to examine the effects of an intrinsically motivating goal, as discussed by Malone (1981). It appears to have motivated participants sufficiently to have had positive effects in terms of on-task behaviour. However, there remains some discrepancy between the effect of the points system on on-task activity and its effect on error making. Despite more time spent on-task when completing the Black and White *Simpsons* Points Task and the Coloured *Simpsons* Points Task reductions in impulsive responding were seen for the tasks that involved character without points.

As suggested in the conclusion of Study 4, it is possible that the costs and rewards involved in the points system were sufficient to increase attention of children with ADHD but not to affect their performance to the same degree. As before this has interesting implications concerning the role of motivation in ADHD and the distinction between different types of executive processing. Rather than being a set of inter-dependent processes, the acts of paying attention while resisting interference and inhibiting a

primary ongoing response may be distinct, independent processes. Furthermore, these different processes may be activated by different contextual features such as different degrees of incentive. The possible interpretations of these findings will be discussed further in Chapter 10.

In summary, the results of Study 5 are largely consistent with those from the previous two studies. Performance in terms of error making and on-task activity of participants with ADHD, the EF processes said to be problematic for these children, were seen to improve when completing the specially designed computerised tasks. These tasks were designed to investigate features thought to be more interesting and motivating for the child with ADHD. In this instance these features were the addition of meaningful characters and a points system. These results have implications for research methodology. A possible dissociation between behaviour and performance emerged in Study 4. The task feature of meaningful character was found to be particularly important in enhancing the ability of children with ADHD to inhibit an ongoing response. The task feature of a points system was found to be particularly important in increasing their on-task behaviour.

7.8.2 Auditory and Visual Processing and Reinforcement

Results from all studies, and particularly Study 5, pointed to a need to consider processing demands of different tasks and the interaction with the ability to inhibit. Another possible explanation for increased error making of participants with ADHD despite increased on-task activity for tasks that involved the points system concerned the processing demands placed upon participants. Tasks with points presented additional visual information in the form of a coloured box in which the number of points gained were presented. This was presented in the top right hand corner of the screen. Jancke *et al.* (2000) found that responses made in the context of a visual task were generally more variable than the same responses made in the context of auditory stimuli. They argued

that differences in behaviour were evidence that different types of motor control are used during auditory and visual processing. In particular visual tasks were thought to involve more complex processing reliant on different controlling modes than auditory tasks. Whereas auditory tasks were hypothesised to require internal motor control, visual tasks were hypothesised first to require motor control and then secondary processes that rely on motor control. As such the two methods of presentation were thought to require the use of different processing pathways. This may account for some of the differences in performance and behaviour exhibited by participants with ADHD.

There are additional studies that argue that visual processing speed differs significantly, and is slower, in ADHD, for example, performance on rapid visual matching tasks has been associated with behavioural indices of ADHD (Barkley, 1991; McGee *et al.*, 2000).

7.8.3 Conclusion

To conclude, differences in performance and on-task activity exhibited by participants with ADHD were found with manipulations made to the testing context and task features. With reference to the results of Study 3, findings suggested that the addition of a meaningful character might account for the improvements in performance seen for these children in terms of both error making and on-task activity observed between the *Pokémon* task and the CPT II. However, as observed in Study 4, results indicated that the addition of the points system produced a counter intuitive finding, and large improvements in on-task attention were not entirely consistent with smaller reductions of error making of participants with ADHD. The additional visual information contained in the Points Task and Points with Story Task may have positively affected on-task attention, but negatively affected the participant with ADHD's ability to inhibit an ongoing response relative to other tasks. This could be a reflection of distraction of visual information from the main aim of the task, increased demands of visual tasks on processing resources or more complex processing reliant on different processing

pathways. This would have required more effort and processing. It therefore seemed crucial that investigation into the effects of additional visual processing be investigated.

Chapter 8

Effects of auditory feedback, reward and response cost on performance of children with ADHD and TD children on computerised tasks.

Introduction

The previous studies examined the performance and behaviour of children with ADHD and TD children on several modifications of a computerised task designed to assess impulsive responding and attention. The tasks were modified versions of the Conner's Continuous Performance Test II. Findings suggested that in contrast to TD participants, who did not perform or behave differently across tasks, participants with ADHD produced fewer commission errors on modifications that included the addition of story and character. The addition of a points system, both in isolation and addition to character, increased the on-task behaviour of children with ADHD. Participants with ADHD were less distracted and fidgety and more attentive. However, without the addition of character this points system produced higher numbers of commission errors for children with ADHD.

There appeared to be a counter intuitive discrepancy between the effect of this points system on the behaviour of children with ADHD and its effect on their performance. This has interesting implications concerning the role of motivation and the distinction between the different processes involved in impulse control, attention and resistance to distraction. Results pointed to a need to consider the processing demands of different tasks and interaction with performance. The points system involved presentation of additional visual information. Study 6 therefore investigated the use of a points system that provided auditory feedback rather than a visual representation of the participant's score.

Another possible explanation for the effect of the point system on performance and behaviour concerns the sensitivity of individuals with ADHD to different types of reinforcement and response cost. The aim of Study 7 was therefore to examine the role reinforcement and response cost in ADHD.

8.1 Study 6. Effect of auditory feedback on performance of children with ADHD and TD children on a computerised task.

The aim of Study 6 was to investigate the possibility that the additional visual information involved with the points system positively affected the on-task attention of children with ADHD, but negatively affected their ability to inhibit an ongoing response in comparison to performance and behaviour on the Short CPT II. This could be due to distraction of additional visual information, increased demands on processing resources or more complex processing reliant on different processing pathways (Jancke *et al.*, 2000).

Following Study 5 it was hypothesised that in contrast to TD participants, who would not perform differently across tasks, participants with ADHD would perform better on a task where visual processing demands of the points system were reduced and feedback was auditory compared to performance and behaviour on the Short CPT II.

It was therefore predicted that:

- there would be no difference in the performance and activity of TD participants across tasks;

but that participants with ADHD would:

- produce fewer errors on the Auditory Points Task than on the Short CPT II
- exhibit more on-task activity on the Auditory Points Task than on the Short CPT II.

8.2 Method

8.2.1 Design

The study was again of mixed design, the performance of participants with ADHD and TD participants was compared across tasks. The dependent variable tested was again commission errors and on-task activity. Two tasks modified from the Conners' CPT II were used. The presentation of tasks was counterbalanced.

8.2.2 Participants

A new group of participants with ADHD were approached and recruited at the Learning Assessment and Neurocare Centre in Horsham, West Sussex, based on the same criteria used for previous studies. These were matched with TD participants, some of whom had taken part in previous studies and some of whom were newly recruited, on level of experience with computers and on their Raven's Progressive Matrices score, used as an indication of non-verbal IQ. All children rated themselves as being somewhat experienced to very experienced on computers, the most frequently received rating was Experienced. A total of twenty children with ADHD and twenty TD children participated in this study. Of these children two participants from each group were female, the remaining eighteen from each group were male. The age of participants with ADHD ranged from 4 years 11 month to 15 years 8 months, mean age 10 years and 2 months (SD 3.2). The age of TD participants ranged from 4 years 0 months to 14 years 11 months, mean age 8 years 3 months. Participants met the criteria for ADHD stated in Studies 3-5. A total of 7 participants with ADHD had co-morbid disorders, including Asperger's Syndrome (3), Dyslexia (1), Dyspraxia (2), Oppositional Defiance Disorder (5), Learning Disabilities (3) and Semantic Pragmatic Language Disorder (1). These were taken into account during statistical analyses.

Table 12.

Characteristics of ADHD and TD participants in terms of Age, Raven's Progressive Matrices Score and General level of experience with computers.

	Age (SD)	Mean Ravens' Progressive (SD) Matrices Score		General Level of Experience with Computer Games
ADHD	10.2 years (3.22)	50 th per centile	(6.93)	Experienced
TD	8.3 years (2.90)	50 th per centile	(8.45)	Experienced

8.2.3 The Tasks

The Short CPT II

Computer generated letters were presented at inter-stimulus intervals of 2 seconds, with a display time of 250 milliseconds, for a duration of 4 minutes 30 seconds. The participant was required to press the space bar in response to all letters apart from the target letter X. A total of 12 targets were presented.

The Auditory Points Task

Participants were presented with a replication of the Short CPT II with the addition of a points scoring system. However points were indicated using auditory feedback. As for the points tasks used in Studies 4 and 5 participants received 10 points for every letter responded to, apart from the X. A deduction of 10 points was made for incorrect responses to the X. Instead of presenting points visually in the top left corner of the screen, a 10 points gain was indicated with a 'ding' sound and a 10 points loss with a vocal 'No'.

8.2.4 Procedure

As for Studies 3, 4 and 5 participants with ADHD's parents and their consultants agreed to allow participants to abstain from taking medication 4 hours prior to testing.

Participants continued to take their medication as normal as soon as testing finished, but

as for all previous studies it must be acknowledged that residual methylphenidate may have affected performance of participants with ADHD.

The participants were tested in a room at the Learning Assessment Centre or in their homes. As for previous studies the setting was informal and naturalistic and there were distracting objects including a television and toys in the rooms.

As before, participants were asked if they would like to help the experimenter and play a few games on the laptop. Participants were then presented with the two computerised tasks in counterbalanced order.

For each task the experimenter explained 'The computer will show lots of letters on the screen one at a time. You will need to press the spacebar for all of the letters that you see except for the letter X, the one that looks like this.... Please press the spacebar as quickly but also as accurately as possible. Remember please press the spacebar for any letter you see apart from the X. First we will have a quick practice session and then I will let you play the whole game. The game will last for 4 and a half minutes. When you click the OK button, the session will start'.

For the Auditory Points Task participants were told that they would receive 10 points for every letter, apart from the X, responded to and that a deduction of 10 points would be made if they incorrectly responded to the X. They were informed that they would not see their score until the end of the task. They were told that they would hear a 'ding' sound for every 10 points they gained, but a 'No' every time they lost 10 points by incorrectly responding to the X.

After receiving the task's instructions the experimenter demonstrated what was required. As in previous studies participants were given a 70 second practice session after which they were left to complete the task. The experimenter explained that she would be sitting quietly at the back of the room if the child needed her.

On completion of the first task the experimenter thanked the participant for their participation and asked if they would like to play the second 'game'. All participants responded positively. On completion of the second task participants were complimented on their performance and thanked for their participation.

8.2.4 Coding

All measures were the same as those used in studies 3-5, commission and omission errors were recorded by the computer programme and on-task activity was recorded by the experimenter. Inter-observer ratings analysed using Cohen's Kappa produced a k value of 0.99.

8.3 Results

8.3.1 Performance data: Errors

In order to control for potential differences in overall levels of responding of both groups of participants on the tasks omission errors were included in the following analyses. In order to examine performance the commission errors produced by both groups of participants were examined. The mean commission errors and their standard deviations (SD) produced on the two tasks are presented in Table 13.

Table 13.

Mean commission errors produced on the Short CPT II and Auditory Points Tasks.

		Short CPT II	Auditory Points Task
ADHD	(SD)	8.96 (2.34)	7.49 (3.41)
TD	(SD)	7.35 (1.53)	6.90 (2.05)

Examination of mean scores showed that both groups of participants produced the most errors on the Short CPT II and the fewest errors on the Auditory Points Task.

Contrary to the prediction that participants with ADHD would produce fewer errors on the Auditory Points Task a mixed ANCOVA conducted on these data, using Ravens'

scores and omission errors as covariates, did not revealed significant effects of either group ($F(1,37) = 3.24$; $p = 0.08$, observed power 0.41) or task ($F(1,37) = 0.57$; $p = 0.455$, observed power 0.11) on error making of both ADHD and TD participants, nor was an interaction observed ($F(1,37) = 0.952$; $p = 0.33$, observed power 0.16).

8.3.2 Performance data: Observations

The mean number of 10-second intervals spent by participants engaging in on-task and off-task behaviour while completing the two tasks is recorded in Table 14.

Table 14.

Mean number of 10-second intervals spent engaging in on-task activity while completing the Short CPT II and Auditory Points Tasks.

	ADHD (SD)	TD (SD)
Short CPT II	11.40 (6.30)	20.80 (2.41)
Auditory Points Task	17.30 (3.73)	21.20 (2.69)

Examination of Table 14 reveals that both groups of participants exhibited more on-task activity on the Auditory Points Task than the Short CPT II.

A mixed ANCOVA conducted on this data, using Ravens's scores as a covariate, revealed a significant effect of group ($F(1,37) = 47.81$; $p < 0.001$). But an effect of task was not found ($F(1,37) = 1.49$; $p = 0.23$, observed power 0.22) on on-task activity. A significant interaction between group and task was also revealed ($F(1,37) = 8.24$; $p < 0.01$). The nature of this interaction is shown in Figure 11.

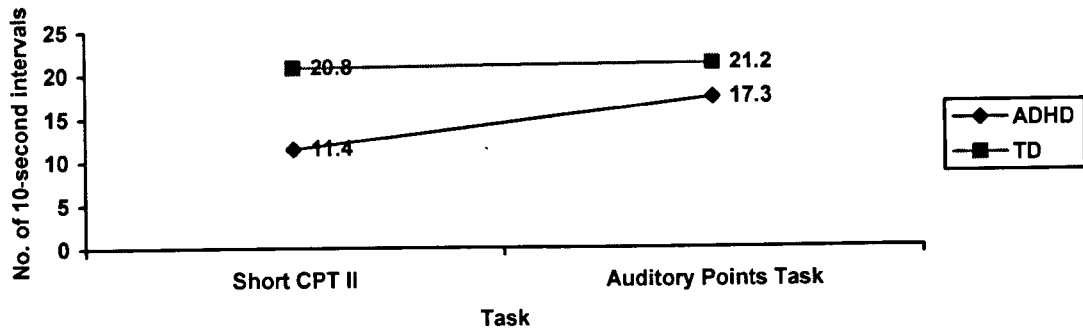


Figure 11. On-task activity exhibited by participants with ADHD and TD participants on the Short CPT II and Auditory Points Task.

Further analysis revealed that the on-task performance of participants with ADHD differed significantly from that of TD participants on the Short CPT II ($F(1,39) = 6.572; p < 0.05$), but that the on-task activity exhibited by the two groups on the Auditory Points Task was not significantly different ($F(1,39) = 0.433; p = 0.515$, observed power = 0.10).

In addition, further planned comparison were conducted in order to test the prediction that participants with ADHD would exhibit a performance enhancement in terms of more on-task activity on the Auditory Points Task than on the Short CPT II. As predicted, this one way ANCOVA conducted on the behavioural observation data revealed a significant difference between the on-task activity exhibited on the two tasks by participants with ADHD ($F(1,18) = 13.652; p < 0.005$). This difference was in the direction predicted, examination of the mean number of 10-second intervals spent on-task showed more on-task activity for the Auditory Points Task. In contrast a one way ANCOVA revealed that TD participants did not exhibit significantly different amounts of on-task activity across the two tasks ($F(1,18) = 0.095; p = 0.762$, observed power = 0.06).

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANCOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on these tasks ($F(1,17) = 0.15; p = 0.703$, observed power = 0.07).

8.4 Study 6 Discussion

8.4.1 Summary of Findings

As predicted TD participants did not perform or behave differently across tasks. However, contrary to prediction participants with ADHD also did not produce significantly fewer errors on the Auditory Points Task compared to the Short CPT II. This finding was consistent with that from the Points Task in Study 4. However, participants with ADHD, as predicted, exhibited significantly more on-task activity on the Auditory Points Task. This is consistent with all visually reinforced points tasks used in Studies 4 and 5.

This consistency and lack of effect of auditorally reinforced points on error making indicated that the additional visual information incorporated in the points system was not responsible for the observed poorer performance in Studies 4 and 5. This provided no support for the hypothesis that additional visual information distracted from the main aim of the task and increased processing demands.

The results suggested that both visual and auditory forms of reinforcement were insufficient to improve attention and inhibition of an ongoing response for participants with ADHD where the points system was added to the tasks. The implication was that alternative explanations for error making despite increases in on-task activity were needed for this group of participants.

This finding was consistent with that of McGee *et al.* (2000). These researchers also designed an auditory CPT to investigate effects of visual processing on the performance of participants with ADHD. These researchers claimed a high degree of association between the Conners' CPT and their auditory version of the task. Findings showed concordance on 67 per cent of the sample between the visual and auditory versions. These researchers also concluded that the auditory version was perhaps more 'boring' and suggested that poor performance could be attributed to this factor.

8.4.2 Reinforcement

The results of Study 6 were consistent with those from all previous studies in that they suggested that performance was contextually dependent for participants with ADHD. It was hypothesised that motivation may have been particularly influential. This could be intrinsic to the task or manipulated by external factors such as the addition of reinforcement in the form of the points system. It was perhaps significant that these were the tasks for which findings are more complex. Despite improvements in on-task activity for participants with ADHD on these tasks, their impulsive error making remained poor or became worse. It was therefore decided that the impact of this type of reinforcement required further investigation. It may be that participants with ADHD lacked sensitivity to reinforcement particularly if they have a high reward threshold (Barkley, 1997b; Haenlein & Caul, 1987; Solanto, 1990; Wender, 1971). The implication of this is that rewards would need to be high in order to have a reinforcing effect for children with ADHD.

Alternatively participants with ADHD may experience heightened sensitivity to reinforcement. Douglas and colleagues have proposed that due to an impaired capacity to modulate arousal level individuals with ADHD are oversensitive to rewards (Douglas & Parry, 1983). Giving rewards and taking them away (response cost) can trigger arousal. The nature of the reinforcer will determine whether arousal is triggered

to either an optimal or supra-optimal level. Douglas (1989) observed that children with ADHD exhibited an increased inclination to seek immediate rewards, but over reaction to failure to obtain reward. In terms of positive effects Douglas found that while intrinsic and continuous reinforcement were most effective in improving performance, continuous and partial reinforcement also had an impact on performance relative to no reinforcement (Douglas & Parry, 1983). Over sensitivity may have increased the impact of reward and reinforcement, therefore improving inhibitory performance.

However, over sensitivity may also have negative impacts on performance, it may cause individuals with ADHD to react more impulsively so as to gain rewards (Freibergs & Douglas, 1969; Parry & Douglas, 1983; Douglas & Parry, 1983; Firestone & Douglas, 1975) or may lead to unusually strong adverse reactions to loss of reward or failure to obtain expected rewards (Barkley *et al.*, 1980; Quay *et al.*, 1967; Wolraich *et al.*, 1978; Worland, 1976). Amsel (1968) suggested that when reward is withheld participants become frustrated. As a result when they encounter the same situation again they experience anticipatory frustration. This prompts conflicting messages to both approach and avoid, resulting in slower responding as participants must choose how to react. Amsel proposed that this is resourcefully demanding and distracts from the primary aim of the task.

Claims have also been made that taking away rewards (response cost) is a more effective strategy than giving rewards for individuals with ADHD (Carlson & Tamm, 2000; Carlson *et al.*, 2000; DuPaul *et al.*, 1992; Firestone & Douglas, 1975; Pfiffner & O'Leary, 1987; Rapport *et al.*, 1982; Worland, 1976). For example, Carlson *et al.* (2000) examined the effectiveness of reward, response cost and no response on performance on arithmetic tasks of children with ADHD in conditions of high and low interest. Results showed that both reward and response cost improved performance

compared to no reinforcement, but that response cost had the most significant effect. This was evident for both high and low interest conditions.

Several explanations have been offered for these findings. Giving rewards may be superfluous and emphasise task participation (behaviour) rather than performance quality (error making). This is consistent with the claims of Douglas that over sensitivity to gaining rewards may make participants more likely to respond quickly to all stimuli in order to gain rewards despite the fact that this increases the likelihood of error making. Carlson and Tamm (2000) suggested that negative feedback increases focus on error making, unlike reward that increases focus on task orientated responses. Douglas and Parry (1983) suggested that penalty for incorrect responses improves caution. Caution involves hesitancy and thus provides more delay before responding. This may explain reduced impulsivity for participants with ADHD where costs are involved.

Such explanations may account for findings of increased on-task activity but increased impulsive error making on tasks that incorporated the points system for this group of participants in Studies 4 and 5. The addition of points could have undermined the incentive and motivation to participate in the 'games' and drawn attention away from the aim of the task and towards gaining points. This is consistent with the findings of Firestone and Douglas (1975) who reported that rewards shortened response times but led to an increase in impulsive errors.

Like Carlson and colleagues, Iaboni *et al.* (1995) also investigated effects of both reward and response cost on the inhibitory performance of children with ADHD. Participants with ADHD showed optimal performance under combined reward and response cost contingencies. Iaboni *et al.* suggested that rewards increased motivation and response cost made salient signals for inhibition, thus optimising performance. However, such research emphasises a need to consider relationships between

contingencies, contextual factors and the effectiveness of reinforcement. Similarly, Haenlein and Caul (1987) hypothesised that the debate over sensitivity or under sensitivity is irrelevant and highlights the need for specific identification of relationships between different types of reinforcement and task demands.

8.4.3 Conclusions

In summary, the empirical research reviewed in this discussion suggests that in order to improve the performance of participants with ADHD tasks need to be manipulated to increase focus on response costs and relationship to error making. This might be achieved with appropriate reinforcement or punishment that is both relevant tangible and consistent.

If individuals with ADHD are less sensitive to reward it follows that by increasing the level of reward improved performance should eventually occur. However, if individuals with ADHD are over sensitive to reward then it follows that too much reward may impair performance due to over stimulation or distraction. Instead, it may be more effective to manipulate level of response cost. This may improve their focus on correct responding, avoid problems of too little reward and over ride any distraction to achieve rewards rather than perform well. In order to gain a more comprehensive understanding of the nature of the relationship between inhibition and reward and response cost contingencies in ADHD further manipulation of task, task condition and magnitude of response cost (Solanto, 1990) was therefore proposed.

8.5 Study 7. Effects of reward and response cost on performance of children with ADHD on computerised tasks.

Studies 3-6 examined the performance and behaviour of TD children and children with ADHD on several modifications of a computerised task designed to assess performance in terms of inhibitory control and attention (the CPT II). The findings suggested that

while TD participants performed and behaved similarly across all tasks, participants with ADHD produced fewer commission errors (indicative of a reduction in impulsive responding) to modifications of the standardised task that included the addition of character (Study 5). The addition of a points system, both in isolation (Studies 4 and 6) and in addition to character (Study 5), increased on-task activity for children with ADHD. But without the addition of character this system produced higher numbers of commission errors for these participants (Study 4). In order to explore this counter intuitive finding visual reinforcement was replaced with auditory reinforcement (Study 6). Auditory reinforcement of the points system again helped to improve on-task activity of children with ADHD but did not help to reduce their commission errors. This indicated that additional visual information involved with the points system was not responsible for increased error making. This cast doubts on claims that additional visual information distracted participants with ADHD from the main aim of the task or increased processing demands. An alternative account was sought.

Sonuga-Barke (2002) hypothesised that there are two independent processing pathways responsible for the deficits in inhibition exhibited by individuals with different forms of ADHD. For some individuals inhibitory problems are said to result from dysfunction of the meso-cortical branch of the dopamine system. However, for others, dysfunction of a separate meso-limbic dopamine pathway responsible for 'delay aversion motivational style' results in impulsive responding and hyperactivity. Importantly, this theory focuses on the potential impact of increased activation of motivation on the performance and behaviour of children with ADHD. In line with this theory it is may have been that the changes made to the contextual characteristics of character and story resulted in increases in motivation sufficient to help overcome impulsive responding and inattentive behaviours.

Johansen *et al.* (2002) proposed a dual pathways theory of ADHD that focused primarily on altered sensitivity to reinforcement resulting from dysfunction of the meso-limbic-cortical dopamine system. Investigations of reaction to reinforcement and punishment of participants with ADHD has suggested that performance depends upon motivation and effects of different types or degree of reinforcement or punishment. Poor performance of individuals with ADHD has been attributed to altered sensitivity to reinforcers. This results in faster erosion of learnt associations between stimuli, responses and reinforcers, or failure for learning to take place. Where motivation is increased reinforcement is more effective. There is some debate about whether this reflects lowered sensitivity (Solanto, 1990) or over sensitivity to reinforcers (Douglas & Parry, 1983). There is also debate about whether punishment is more effective than positive reinforcers.

The aim of Study 7 was to examine the role reinforcement in ADHD. It was assumed that increased incentive might help to stimulate functioning of the mechanisms responsible for the improvements in performance seen in the previous studies. According to Johansen *et al.* increased incentives should promote sensitivity to reinforcers and thus functioning of both the dopamine pathways responsible for impulsive responding, impulsive cognition and excessive motor activity. Reinforcers must be sufficiently motivating to facilitate the predicted compensatory action. Response cost was thought to be both more arousing and effective at focusing attention on error making. Manipulations of the level of incentive associated with the points system used in earlier studies were made. Following Study 6 it was hypothesised that TD participants would continue to perform and behave similarly across tasks. In contrast it was hypothesised that participants with ADHD would perform better on tasks where a higher cost was associated with making an impulsive error compared to the shortened CPT II. It was therefore predicted that:

- there would be no difference in the performance and behaviour of TD participants across tasks;

But that participants with ADHD would:

- produce fewer errors on tasks that removed 50 and 100 points for incorrect responses compared to the Short CPT II and
- exhibit more on-task activity on tasks that removed 50 and 100 points for incorrect responses compared to the Short CPT II.

8.6 Method

8.6.1 Design

The study was again a mixed design. The independent variable tested was again performance in terms of commission errors and on-task activity. Four modifications of the Conners' CPT II were used. The presentation of tasks was counterbalanced.

8.6.2 Participants

Participants who had taken part in Study 6 were approached. All twenty children with ADHD and all twenty TD children participated in this study. Two participants in each group were female, and eighteen male. The age of participants with ADHD ranged from 4 years 11 month to 15 years 8 months with a mean age 10 years and 2 months (SD 3.2). The age of TD participants ranged from 4 years 0 months to 14 years 11 months, mean age 8 years 3 months. Further details of participant characteristics can be found in section 8.2.2.

8.6.3 The Tasks

Participants were presented with three modifications of the Short CPT II used in Studies 4-6 involving the addition of a points scoring system, presented in the right hand corner of the screen.

The Short CPT II

Results were collected in Study 6.

The 10 Points Task

For the 10 Points Task participants received 10 points for every letter, apart from the X, responded to. A deduction of 10 points was made when the participant incorrectly responded to the X.

The 50 Points Task

For the 50 Points Task participants again received 10 points for every letter, apart from the X, responded to. However, a deduction of 50 points was made when the participant incorrectly responded to the X.

The 100 Points Task

For the 100 Points Task participants also received 10 points for every letter, apart from the X, responded to. This time a deduction of 100 points was made when the participant incorrectly responded to the X.

8.6.4 Procedure

As for studies 3, 4, 5 and 6 participants abstained from taking medication 4 hours prior to testing. They continued to take their medication as soon as testing finished, however residual methylphenidate may have affected performance. Participants' parents and consultants had agreed to this arrangement for both this and the previous study (Study 6). As for Studies 3, 4, 5 and 6 participants completed the tasks in a room at the Learning Assessment Centre that contained distracting objects, including a television and toys.

Participants were asked if they would like to help the experimenter again by playing some more games on the laptop 'just like before'. Participants were then presented with the three computerised tasks. The order of the three points tasks was counterbalanced. Results on the Short CPT II had been obtained from the participants in Study 6.

As for Study 6, for each task the experimenter explained 'The computer will show lots of letters on the screen one at a time. You will need to press the spacebar for all of the letters that you see except for the letter X, the one that looks like this.... Please press the spacebar as quickly but also as accurately as possible. Remember please press the spacebar for any letter you see apart from the X. First we will have a quick practice session and then I will let you play the whole game. The game will last for 4 and a half minutes. When you click the OK button, the session will start'.

For each of the Points Tasks the experimenter also explained the scoring system. The participant was told that 10 points would be given every time they press the spacebar when they saw a letter. But that 10/50/100 points would be taken off their score if they pressed the spacebar when they saw the X.

After receiving the task's instructions the experimenter demonstrated the task and desired responses to the participants who were then presented with a 70-second practice session. Participants were then left to complete the first task. The experimenter explained that she would be sitting quietly at the back of the room if the child needed her. After each task was completed the experimenter returned to the child thanked them for their participation and asked if they would like to play the next 'game'. On completion of the last task participants were complimented on their performance and thanked for their participation.

Performance was coded as for Studies 3-6, commission errors were used as a measure of impulsive responding and activity was recorded using a 10-second interval recording system by the experimenter from an unobtrusive location at the back of the room.

8.7 Results

8.7.1 Performance data: Errors

In order to control for potential differences in overall levels of responding of both groups of participants on the tasks omission errors were added as a covariate in subsequent analyses.

In order to examine performance the commission errors produced by both groups of participants were examined. The mean commission errors and their standard deviations (SD) produced on the four tasks are presented in Table 15.

Table 15.

Mean commission errors produced by participants with ADHD and TD participants on the Short CPT II (Study 5) and the 10, 50 and 100 Points Tasks (Study 6).

	Short CPT II		10 Points Task		50 Points Task		100 Points Task	
ADHD (SD)	8.96	(2.34)	7.96	(3.59)	9.17	(2.65)	7.12	(3.44)
TD (SD)	7.35	(1.53)	7.15	(1.67)	6.80	(1.67)	6.75	(1.62)

Examination of mean scores shows that participants with ADHD produced the most errors on the 50 Points Task. The second highest error rate was seen for the Short CPT II, followed by 10 Points Task. The fewest errors were produced on the 100 Points Task. TD participants produced the highest error rate on the Short CPT II and the lowest error rate on the 50 Points Task.

A mixed ANCOVA conducted on these data, using Ravens' scores and omission errors as covariates, did not reveal a statistically significant effect of group ($F(1,33) = 1.66; p = 0.207$, observed power 0.24), nor a statistically significant effect of task ($F(3,99) = 0.77; p = 0.515$, observed power 0.20) on impulsive error making. However, a significant interaction between group and task was found ($F(3,99) = 2.69; p = 0.05$, observed power 0.58). This interaction can be seen in Figure 12.

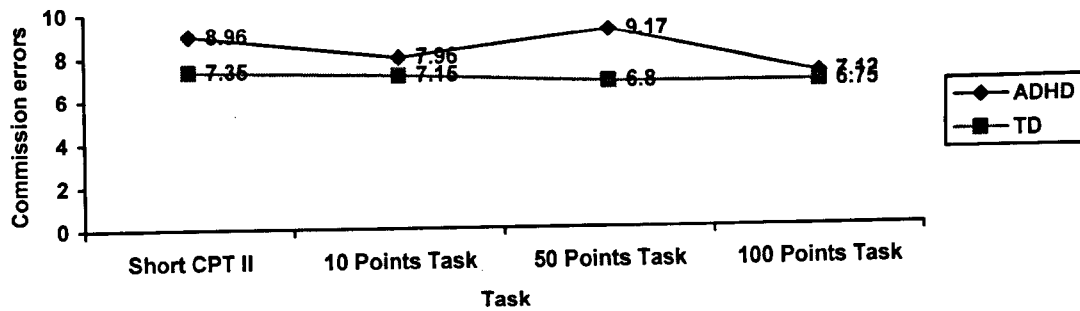


Figure 12. Commission errors exhibited by participants with ADHD and TD

participants on the Short CPT II, 10 Points Task, 50 Points Task and 100 Points Task.

As predicted, a one way ANCOVA conducted on the data produced by TD participants did not reveal a significant difference in error making across the four tasks ($F(3,42) = 0.935; p=0.432$).

In order to test the prediction that participants with ADHD would produce fewer errors on tasks that removed 50 and 100 points for incorrect responses compared to the Short CPT II planned comparisons were conducted. As predicted these revealed a significant difference in error rates on the 100 Points Task compared to the Short CPT II ($F(1,16) = 4.715; p<0.05$). However, although error rates on the 50 Points Task were greater than errors on the Short CPT II, this difference was not statistically significant. Consistent with findings from Study 4, one way ANCOVA revealed that error rates on the 10 Points Task compared to the Short CPT II were not significantly different ($F(1,16) = 2.004; p=0.176$ observed power = 0.26). It is important to note at this point that error making on the 10 Points Task was higher in Study 4 than in the present study. However, this was accompanied by higher error making on the CPT II in Study 4. This might be accounted for by the younger age of participants in the earlier study, where the mean age was 8 years compared with 10 years, 2 months in the present study.

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANCOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and performance on these four tasks ($F(3,51) = 1.106$; $p = 0.355$, observed power = 0.28).

8.7.2 Performance data: Observations

Observations were made of on-task and off-task behaviour. Mean time spent by participants engaging in on-task activity whilst completing the four computerised tasks is recorded in Table 16.

Table 16.

Mean number of 10-second intervals spent engaging in on-task and off-task activity while completing the Short CPT II, and 10, 50 and 100 Points Tasks.

	ADHD (SD)	TD (SD)
Short CPT II	11.40 (6.30)	20.80 (2.41)
10 Points Task	18.65 (5.23)	21.70 (2.47)
50 Points Task	19.25 (3.92)	22.60 (1.90)
100 PointsTask	19.95 (4.35)	21.95 (2.48)

While participants with ADHD exhibited the most on-task activity on the 100 Points Task, TD participants exhibited the most on-task activity on the 50 Points Task. Both groups of participants exhibited the least amount of on-task activity on the Short CPT II. A mixed ANCOVA conducted on the data produced by ADHD and TD participants, with the covariate of Raven's IQ score, revealed a significant effect of group ($F(1,37) = 27.66$; $p < 0.001$) and task ($F(3,111) = 2.73$; $p < 0.05$) on the number of 10-second intervals spent on-task. This analyses also revealed a significant interaction between

group and task ($F(3,111) = 8.79$; $p < 0.001$). The nature of this interaction can be seen in Figure 13.

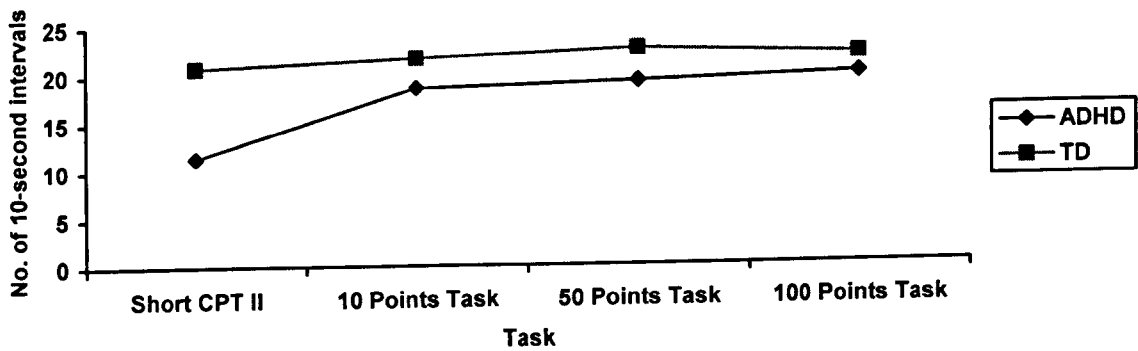


Figure 13. On-task activity exhibited by participants with ADHD and TD participants on the Short CPT II, 10 Points, 50 Points and 100 Points Tasks.

As predicted, TD participants performed similarly on all tasks and a one way ANOVA conducted on these data did not reveal any significant differences in on-task activity across tasks ($F(3,54) = 0.327$; $p = 0.806$, observed power 0.11).

In order to test the prediction that participants with ADHD would exhibit more on-task activity on tasks that removed 50 and 100 points for incorrect responses compared to the Short CPT II planned comparisons were conducted. As predicted these showed significant differences in the amount of time spent engaging in on-task behaviour on both the Short CPT II compared to the 50 Points Task ($F(1,18) = 6.640$, $p < .05$) and the Short CPT II compared to the 100 Points Task ($F(1,18) = 5.809$, $p < .05$).

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANOVA was conducted on the data. Analysis using the presence of a co-occurring disorder as an additional between participant independent variable did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on these four tasks ($F(3,54) = 1.45$; $p = 0.24$).

8.8 Discussion

The results for TD participants across tasks were as predicted and consistent with the previous findings there were no differences in performance and on-task activity across tasks. In contrast, and as indicated by the significant interaction effect, participants with ADHD performed in a more variable manner than TD participants across the four tasks. Consistent with previous findings was the performance of participants with ADHD on the 10 Points Task. Once again, improvements exhibited by participants with ADHD in on-task focus were not accompanied by significant improvements in commission errors. For the 50 points task commission errors were marginally higher than on the Short CPT II, which was considered to have little or no intrinsic appeal, and included no reinforcement. This implied that despite attending more to these tasks participants with ADHD were not able to inhibit impulsive responses. Performance of participants with ADHD was consistent with the 'delay aversive' pattern of responses described by Sonuga-Barke (1995) where participants responded quickly and inaccurately to all stimuli irrespective of reinforcement. Results suggested that children with ADHD were insensitive to these levels of reinforcement. However, omission errors, commission errors and behavioural observations of activity on the 100 Points Task suggested that participants were sensitive to a higher level of punishment. Participants appeared more motivated to stay on task and were able to inhibit impulsive responding with significantly greater success.

It could also be that participants with ADHD were overly motivated by the incentive of gaining points. Thus, where response cost was minimal, they over responded in order to receive rewards despite the fact that this increased the chances of inaccuracy and loss of some points. The loss of 10 and 50 points did not impact a great deal on the total number of points participants were able to gain. Participants could gain several hundred points, despite losing a few 10's or 50's by responding quickly but inaccurately. A total of 108 stimuli were presented, with 18 targets. The maximum possible score was

therefore 900 points. The maximum possible losses for the 10 Point Task was 180 points (leaving a score of 720 points) and for the 50 Points Task was 900 points (leaving a score of 0). In contrast the loss of 100 points in the 100 Point Task had a much greater impact on points gained and could result in a maximum loss of 1800 points (leaving a score of -900 points).

In short, for the 10 and 50 Points Tasks it appeared as if participants with ADHD focused on gaining rewards rather than the primary aims of the task. However on the 100 Points Task it appeared as if focus on impulsive error making increased. The experimenter made the observation that participants with ADHD tended to over respond to stimuli on all tasks, they pressed the spacebar more than once per stimuli. The amount of pressing was not recorded. If confirmed, over responding would support claims that children with ADHD are over motivated to achieve rewards.

Participants with ADHD appeared to have been sensitive to gaining rewards and were able to inhibit task irrelevant distraction and interference in order to focus on the task. In addition, although participants appeared to be insensitive to lower levels of response cost, in terms of the impact on commission error making, they appeared to be sensitive to higher levels of response cost.

The findings suggested that participants with ADHD were sensitive to both positive reinforcement and higher levels of punishment in the form of response cost. Poor performance in terms of error making could be attributed to over sensitivity to gaining rewards. Increased performance in terms of error making could be attributed to sensitivity to high levels of response cost. It may be that participants with ADHD are over sensitive to reward and under sensitive to low levels of response cost. High levels of response cost appeared to have the most significant impact on improvements in both error making and on-task activity.

Once again the results indicated that manipulations of task context directly impacted on the performance of children with ADHD. The different impacts that manipulation of task features had on error making and on-task activity suggested that different mechanisms may have been responsible for poor performance in these two areas. Increased motivation to gain points appeared to facilitate better on-task activity. In contrast, this type of motivation did not improve impulsive error making. It was hypothesised that resources may have been reallocated to gaining points thereby reducing sensitivity to signals for loss of reward. However, findings suggested that a higher level of response cost increased sensitivity to signals for loss thereby increasing focus on correct responding.

Chapter 9

Inhibitory Performance on Commercially Available Computer

Games: An Investigation into ‘Real World’ Competence

9.1 Introduction

The results from Studies 1-7 suggested an effect of context upon inhibitory performance. In particular the results pointed towards motivational effects, both intrinsic and extrinsic. Despite investigation into the role of motivation in ADHD in the late 70's and early 80's, little emphasis has been placed upon motivation and stimulation in relation to ADHD by the cognitive and EF research of more recent years. Perhaps the main reason for this has been the increased focus on single processes or core deficits. It is proposed that this focus on the ‘parts’ has distracted from focus on the ‘whole’. It is argued that this can result in a reductionistic view of real life functioning. Research into core processes has focused on task based performance and has tended not to examine relationships between processes and how these are influenced by different environmental and contextual factors. Furthermore, this type of research provides information about performance in limited, structured settings. This may not reflect fully the competence in complex real world situations. In this respect Studies 3-7 can also be criticised. It is not clear if these are generalisable to real life settings. As Brown (1999) stated:

We might extrapolate to say that testing an individual's ability to press a button quickly when a target appears on a boring computer game, or getting someone to read words printed in various colours on a deck of cards, is not likely to yield very adequate information about their ability to

organise and complete their homework, to plan and prepare a meal, to safely drive their car, or to do other complex tasks that rely heavily upon effective EF.

(Brown, 1999)

For this reason it was proposed that a more naturalistic investigation be carried out in order to examine real life competence. This was the aim of Study 8. The hypothesis was that individuals with ADHD would display no more impulsive responses than TD participants on commercially available games. It was expected that participants would display some errors related to poor inhibitory control but that these errors would be equivalent to those exhibited by TD participants. Results were expected to reflect the contextually dependent nature of inhibitory control and increases in both intrinsic and extrinsic motivation. It was therefore predicted that participants with ADHD would:

- produce equivalent numbers of impulsive errors as TD participants on two commercially available games
- produce equivalent numbers of total responses as TD participants on two commercially available games
- and would produce equivalent amounts of on-task activity as TD participants on two commercially available games.

9.2 Method

9.2.1 Design

The study was of mixed design. The performance of participants with ADHD was examined across games and compared to that of TD children. The independent variable to be tested was inhibitory performance, measured by number of impulsive errors made and the amount of on-task activity exhibited. Two commercially available computer games were employed. The presentation of the games was counterbalanced to control for order effects.

9.2.2 Participants

The same 16 children with ADHD and 16 typically developing children who took part in Study 3 took part in this study. To reiterate, these were paired and matched as closely as possible to control for previous experience with computer games, the games to be used in the study and on their Raven's Progressive Matrices IQ score. Further participant details can be found in section 6.2.2.

9.2.3 The Games and Equipment

Several pieces of equipment were required: a laptop computer; a television; a VCR; a *Playstation* console with one handset and a stop watch. *Averkey 2000* was used to link the laptop to the TV, this allowed projection of the action presented on the laptop monitor to the TV monitor and facilitated recording of performance on the VCR.

Participants were asked to play two commercially available games; *The Revenge of Frogger* (referred to as *Frogger*) presented on the laptop and *Crash Bandicoot II: Cortex Strikes Back* (Universal Interactive Studios, Inc 1997) presented on the *Playstation*.

The aim of *Frogger* was to successfully move a frog across four lanes of traffic and a river to the safety of the river bank. The frog was not allowed to swim across the river and had to be moved by jumping across moving logs and turtles. In order to successfully reach the bank participants were therefore required to stop and wait for appropriate moments at which to move the frog across the road or river. If participants moved their frog into traffic or fell in the river they lost a 'life'. Three lives were given per level of the game. Levels increased in difficulty in terms of speed of moving objects and number of hazards. Participants were allowed to use as many lives as they required and started again from the beginning of the previous level each time they had used all of their lives.

The aim of *Crash Bandicoot II* was to guide the character 'Crash' through different environments avoiding numerous hazards that could claim his life in order to collect

crystals. The child was presented with a story that set the scene and gave a reason for collecting the crystals. In order to successfully avoid hazards participants were required to time their responses and often stop and wait for the appropriate moment in which to move '*Crash*'. Each child was allowed to use as many lives as they required and started again from the beginning of the level each time they used all of their lives.

9.2.4 Procedure

As for all other studies participants were observed in an informal 'playroom' setting, for the majority of participants this was a room in their home. The testing environment contained many distractors including toys, a television, video, computer and so on. The aim was to make the setting as informal and naturalistic as possible. For a few participants testing was in a specially modified playroom at the University or at the Learning Assessment Centre. This was furnished to reflect an informal 'home' setting. Again distracting objects, toys, television and video, pictures etc were placed in the room.

As for Studies 3, 4, 5, 6 and 7 participants' parents and their consultants agreed to allow participants to abstain from taking medication 4 hours prior to testing. Participants continued to take their medication as normal as soon as testing finished.

Participants were asked about their general interest and experience of playing computer games. They were then asked if they had ever played either *Frogger* or *Crash Bandicoot II*, and if so how often. None of the participants had played either of the games more than a few times.

After these initial questions the experimenter explained that she needed the participant to do some quick problem solving puzzles. Participants then completed the *Raven's Progressive Matrices*.

After this was completed participants were praised and asked if they would like to play *Frogger* and *Crash Bandicoot II*. All participants responded positively. Instructions

were then given for the first game. The order of presentations was counterbalanced so that half of the participants completed *Frogger* first and half completed *Crash Bandicoot II* first. The experimenter demonstrated the actions required in order to move the character in the correct way. All children were familiar with a computer keyboard and the handset for the *Playstation*. Participants were given a 70-second practice session. All participants demonstrated that they were able to perform the motor controls required for the game.

After successful completion of the practice session the experimenter explained that participants could now play the game and that they would be video recorded as they did so. Participants were told that they would be left to play the game for 14 minutes after which the experimenter would come and turn the game off. The experimenter explained that she would be sitting quietly at the back of the room if the child needed her. The experimenter recorded on-task and off task activity using the 10-second observation procedure from the back of the room. Error making performance was recorded onto video and scored at a later date.

After the children had completed the first game the experimenter asked them if they would now like to play another game. Instructions for the game were given and demonstrated by the experimenter and a 70-second practice session was given before 14 minutes of game play. Performance was recorded as for the first game. On completion of the second game the experimenter turned the equipment off and praised the child and thanked them for their participation. The testing session was then ended.

9.3 Results

9.3.1 Performance data: Errors

For both games there was no ceiling to the number of responses that could be made and therefore no limit to the number of occasions where an impulsive error could be made. It was considered that each child should be allowed to play as naturalistically as

possible and would therefore be able to choose both the speed and thus how far they proceeded into each level of the games.

The calculation of errors took place after the testing sessions. Impulsive responses on both of the games resulted in the loss of a 'life'. The total number of moves made and the total number of occasions when a move resulted in loss of life were calculated. All tapes were selected in random order for coding and the participant's identity was not revealed. A second independent researcher also coded a randomly selected sample of the tapes in order to check reliability of coding. This method for coding errors was piloted using short samples of game play.

Error scores were calculated by taking the total number of impulsive moves made by each individual on each game and dividing it by the total number of moves made throughout the duration of the entire game by each individual. This gave an indication of the per centage of impulsive errors. Some problems of discrimination between mistimed moves and those resulting from impulsive responding occurred for both observers. This is discussed in more detail in the Discussion section. Despite these difficulties inter-rater agreement on a 10 per cent sample of tapes assessed using Cohen's Kappa (Cohen, 1960) produced a k value of 0.79.

The mean number of moves made and mean per centage of impulsive errors produced by both ADHD and TD participants across the games are presented in Table 17

Table 17

Mean number of moves and mean per centage of impulsive errors produced by ADHD and TD participants on Frogger and Crash Bandicoot.

	<i>Frogger</i>		<i>Crash Bandicoot</i>	
	Mean no. of moves	Mean impulsive errors	Mean no. of moves	Mean impulsive errors
ADHD	369.2	6.95 %	132.8	6.32%
TD	385.4	7.31%	150.3	6.71%

Examination of the mean errors produced by participants with ADHD showed the lowest per centage of errors on *Crash Bandicoot II*. The typically developing participants also produced fewer impulsive errors on *Crash Bandicoot II*.

In order to compare the errors made by participants with ADHD and TD participants on the two computer games a two way mixed ANCOVA, using Ravens's scores as a covariate, was conducted on the data. This did not reveal a statistically significant main effect of group ($F(1,28)=0.125$; $p=0.73$, observed power = 0.06), or game ($F(1,28)=0.076$; $p=0.79$, observed power = 0.06). A significant interaction was not recorded ($F(1,28)=0.003$; $p=0.96$, observed power = 0.05). As predicted participants with ADHD performed as well as TD participants on the two commercially available games in terms of the proportion of impulsive error making.

In addition in order to examine whether participants with ADHD responded more frequently, and thus more quickly, than TD participants the mean number of total moves made by both groups of participants on the two games were analysed. Pairwise comparisons did not reveal a significant difference in the total number of moves made by participants with ADHD compared to TD participants on *Frogger* ($t(15)=-0.558$; $p>0.05$) or on *Crash Bandicoot II* ($t(15)=-0.721$; $p>0.05$). This provided further support for the hypothesis that participants with ADHD were no more impulsive than TD participants when playing the two games.

In addition, to give an indication of whether co-morbid disorders were having any systematic effects on the data, correlation analyses were carried out. These did not reveal any significant correlation between co-morbid disorder and impulsive performance on the two games.

9.3.2 Performance data: Observations

Observations were made of on-task and off-task (distracted, fidgeting, touching other objects in the room and out of seat) behaviour. These measures were mutually exclusive. The mean number of 10-second intervals spent by the ADHD and TD participants engaging in on-task behaviour whilst completing the two computerised tasks and two computer games are shown in Table 18.

Each task and game was presented for a total of 14 minutes, consisting of 84 ten-second intervals. All scores presented are therefore out of a maximum possible of 84. The higher the score the more on-task the participants.

Table 18.

Mean number of 10-second intervals spent engaging in on-task of ADHD and TD participants whilst playing Frogger and Crash Bandicoot.

	ADHD	TD
<i>Frogger</i>	71.62	77.50
<i>Crash Bandicoot</i>	78.75	81.25

Examination of this data revealed that both group of participants exhibited more on-task activity on the game *Crash Bandicoot*. In order to examine inhibitory performance of the two groups of the two groups of participants in terms of the amount of on-task activity exhibited whilst engaging with the two games and in order to test the prediction that children with ADHD would exhibit equivalent levels of on-task activity to TD children when playing commercially available computer games a two way mixed ANCOVA was conducted on the data. This revealed a significant effect of task on performance, both groups exhibited more on-task activity for the game *Crash Bandicoot*

($F(1,28)=5.68$; $p=0.024$), but, as predicted, no significant effect of group ($F(1,28)=2.44$; $p=0.13$, observed power = 0.33) and no significant interaction between group and task ($F(1,30)=0.67$; $p=0.42$, observed power = 0.12) were found.

To give an indication of whether co-morbid disorders were having any systematic effects on the data, a mixed ANOVA was conducted on the data. Analysis did not reveal a statistically significant interaction between co-morbid status and on-task behaviour on the games ($F(1,14)=0.294$; $p=0.596$).

9.4 Discussion

9.4.1 Summary of findings

This study failed to show a significant difference between the inhibitory performance of children with ADHD compared to TD children on the two computer games. Results contradicted widespread empirical research. No support was found for the claim that ADHD is characterised by a core deficit of inhibitory control. As for study 2 the findings did not challenge claims that individuals with ADHD suffer from problems of inhibition. Rather, they suggest that there may be contexts in which inhibitory performance is not impaired. The findings of this study highlighted the importance in distinguishing between performance and competence and suggested that traditional EF research may have revealed more about the nature of performance in restricted contexts and little about 'real world' competence.

The findings of Study 8 suggested that individuals with ADHD have inhibitory competence when playing computer games which supported the anecdotal evidence presented in Chapters 2 and 3. This may be a competence that exists across many settings but due to methodological constraints has not been revealed in research to date, or it may be a competence facilitated by features specific to the computer game playing setting.

9.4.2 Methodological Evaluation

It is however, important to remember the complexity of this methodological approach. Due to its complex nature a wide range of issues might be impacting on performance. The cost of this type of real world measure is loss of systematic control of individual features. Despite this, it remains important that these types of measures are used to complement the standard, more rigorous, approach

Chapter 10

Summary of Studies and General Discussion

A total of 8 studies were conducted across this thesis using computerised tasks and games in order to ascertain the role of context in the executive performance of children with ADHD. While some findings indicated that performance could be enhanced by manipulation of contextual parameters, making computerised tasks more ‘game like’ in their presentation, other findings were more confusing and counter intuitive. The following chapter reviews these studies in terms of participant characteristics, results and conclusions. The findings are discussed in terms of their implications for analysis of contexts effects, theory and models of ADHD.

10.1 Participants

A total of 52 children with ADHD, 52 TD children, 48 parents of children with ADHD and 48 parents of TD children were involved in Studies 1-8. The ages of the children differed slightly per study, but ranged from 4 years 1 month to 15 years 8 months. Just under half of all children with ADHD, 36, had co-morbid disorders that included anxiety (1), Asperger’s syndrome (7), autistic spectrum disorders (2), CD (2), DCD/Dyspraxia (6), Dyslexia (7), Language and communication problems/Semantic Pragmatic Language Disorder (2), LD (6), ODD (12), OCD (2), tics/Tourette Syndrome (2).

10.2 Results

10.2.1 Study 1

Parental reports indicated that children with ADHD experience problems of inhibition, including an apparent inability to sit still, concentrate and pay attention, in daily settings. Significantly more parents of children with ADHD reported that their children showed an interest in playing computer/console/video games and that when playing them they

exhibit better concentration, successful performance and reduced distractibility. In contrast, the majority of parents of TD children indicated that their children did not perform any better when playing computer games than when engaging in most other activities. Significantly more parents of children with ADHD reported that their children were more motivated and more mentally active when playing computer games.

10.2.2 Study 2

Consistent with the suggestions made following the questionnaire study, parents of children with ADHD most frequently rated constant stimulation as the feature they felt contributed to their children's interest in playing computer games. In support of Malone's (1980; 1981) claims, the element of challenge was the second most frequently listed feature. The third most frequently listed feature was the characters in the game. This was consistent with the later findings that all tasks involving the use of character were accompanied with improvements in both impulsive error making and on-task focus. Parents also rated: frequent change in action, providing support for the stimulation seeking hypothesis of ADHD; and meaningful goals; colour; elements of control; and uncertainty, providing support for Malone's claims. Graphics, lack of negative feedback, sound, type of game and speed of the game were also listed by parents.

The majority of parents expressed the view that fast speeds are the best speed of games for children with ADHD's enjoyment, ability to achieve success and ability to sustain attention. None of the parents expressed the view that slow games were the best in terms of enjoyment, success or attention. This provided further support for a stimulation seeking account of ADHD, at least with respect to parental perceptions.

10.2.3 Studies 3 – 8

Results from Studies 3 to 8 were divided into 2 parts: those reflecting performance in terms of error making, and those reflecting performance in terms of on-task activity. The findings are summarised in Figures 14 and 15.

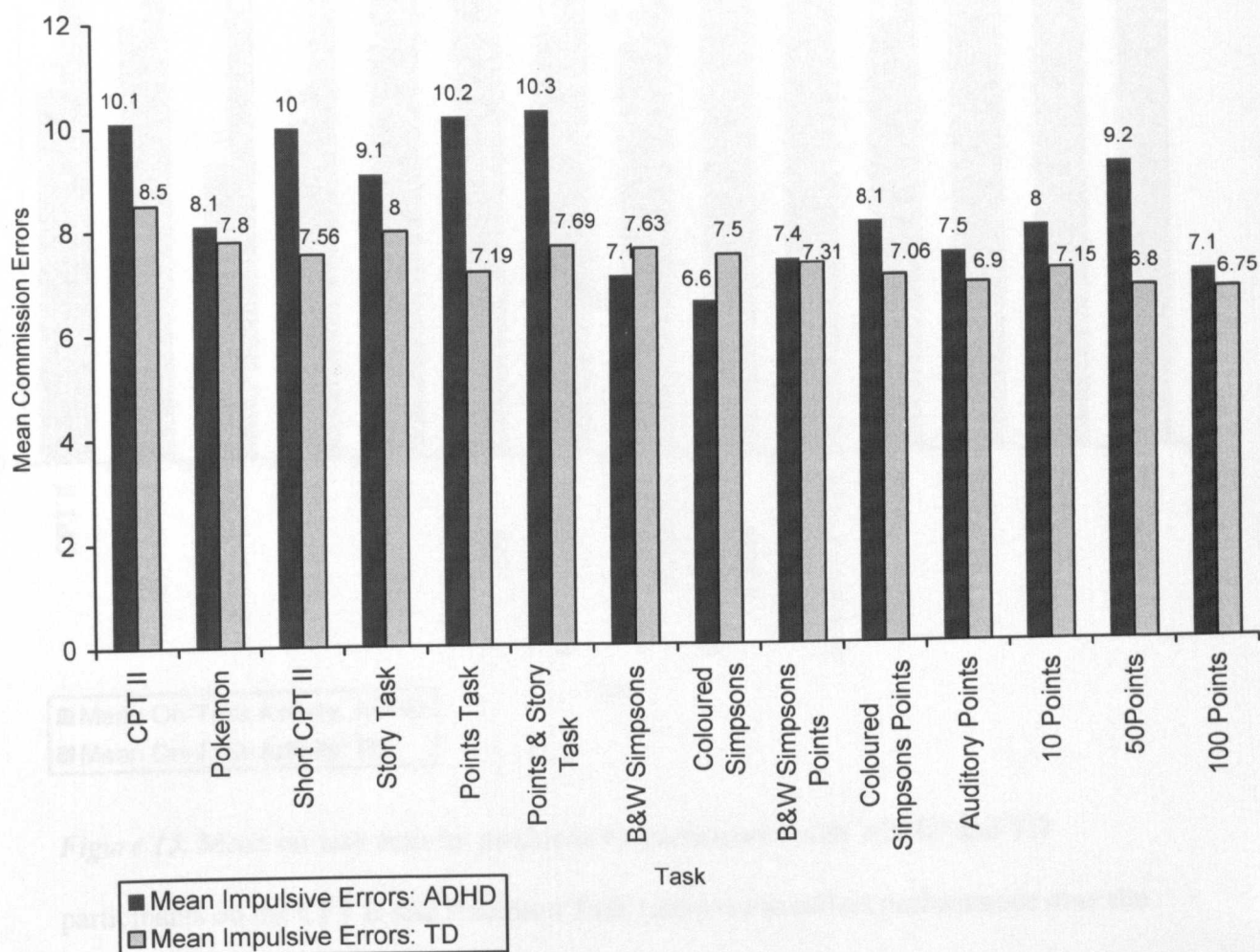


Figure 14. Mean commission errors produced by participants with ADHD and TD participants on the CPT II and Pokémon Task (adjusted to reflect performance over the same duration as later tasks), and on the Short CPT II and twelve ‘game’ versions of the task.

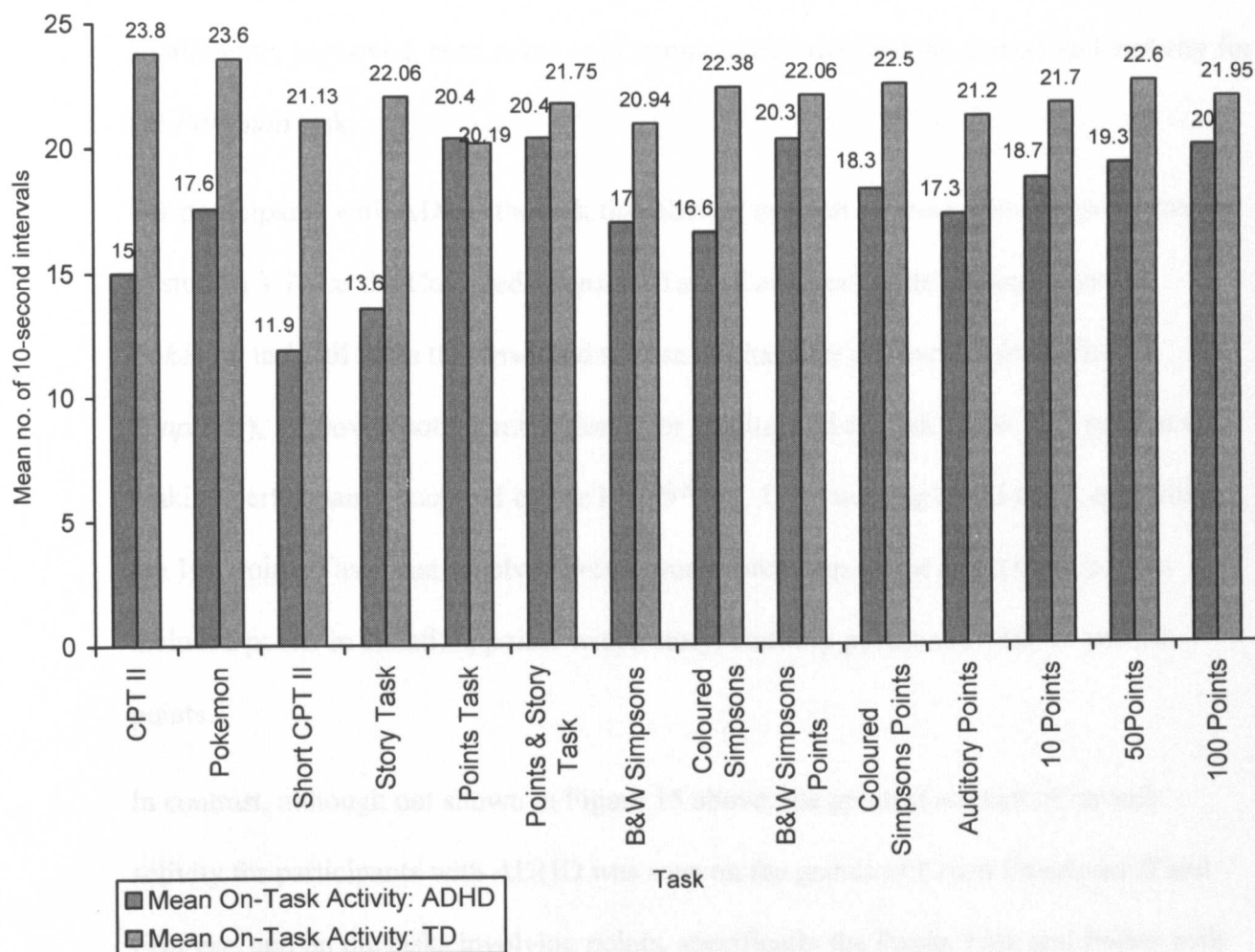


Figure 15. Mean on-task activity produced by participants with ADHD and TD

participants on the CPT II and Pokémon Task (adjusted to reflect performance over the same duration as later tasks), and on the Short CPT II and twelve ‘game’ versions of the task.

It is important to note that the mean errors for *Frogger* and *Crash Bandicoot II* (Study 8) could not be included as they were calculated as per centages and were therefore not comparable. Furthermore, scores on the CPT II and *Pokémon* Task have been modified to make them equivalent to all other tasks (The CPT II and *Pokémon* Task lasted three times longer than the other tasks).

To summarise, the performance of participants with ADHD was significantly impaired compared to TD participants on the standard Conner’s CPT II. Poor performance was seen in both commission error making and on-task activity. However, performance

significantly improved, both in terms of commission error making and on-task activity for the *Pokémon* task.

For participants with ADHD the task that elicited greatest improvements in performance in studies 3-7 was the Coloured *Simpsons* Task. Consistent with findings from the *Pokémon* task, all tasks that involved the use of character (characters from The *Simpsons*), improved both commission error making and on-task focus. The poorest error making performance occurred on the Points Task. Error making on all tasks, excluding the 100 Points Task, that involved points was poorer than on the Short CPT II. This included points in isolation, points with a story, auditory points and both 10 and 50 points.

In contrast, although not shown in Figure 15 above, the greatest amount of on-task activity for participants with ADHD was seen on the games of *Crash Bandicoot II* and *Frogger*, and on the tasks involving points, specifically the Points Task and Points with Story Task. The lowest amount of on-task activity was seen on the CPT II. It is worth noting that apart from the CPT II the Story Task was the only task where on-task activity did not improve.

There were no significant differences in performance between children with ADHD and TD children on *Crash Bandicoot II* and *Frogger*. Both groups performed well and problems of inhibition were not identified in the ADHD group.

10.3 Discussion:

Analysis of Context Effects

The aim of this thesis was to investigate the issue of context effects in relation to children with Attention Deficit Hyperactivity Disorder (ADHD). In order to inform understanding of the possible mechanisms influencing the performance of children with ADHD across settings Chapter 1 outlined some of the literature concerning the inter-relationship

between context and cognition in normal development, contextual sensitivity in general and implications for how we study cognition and conceptualise children's competencies.

This material outlined perspectives on cognition from an emerging school of thought that argues that cognition is always 'situated'. This material suggested that performance will differ across contexts depending upon the interactions that take place between individual and situational characteristics.

Sternberg (1994) described five key individual characteristics that shape the potential of a person: their abilities (both mental and physical), knowledge, thinking and learning style, personality and motivation. Of particular interest to this thesis were memory-analytic abilities (*metacomponents*, higher order processing skills involved in planning, monitoring and evaluating activity; *performance components*, responsible for execution of the instructions given by the metacomponents; and *knowledge acquisition components*, implicated in learning). Deficits associated with each of these memory-analytic skills (referred to as executive deficits in Chapter 2) are hypothesised to be at the heart of ADHD. The interaction of contextual features with the memory-analytic skills of children with ADHD, was therefore a central focus of this thesis. The possible impact on these children's skills of the contexts presented to children with ADHD across the course of the empirical chapters is discussed in the following sections.

Sternberg (1994) also discussed the issue of motivation, which he described as the single most important personal attribute for success and learning. In line with Sternberg's claims it is hypothesised in the following sections that motivation may indeed have been a very important variable impacting on the child with ADHD's performance.

In addition, of specific interest for this thesis was the influence context exerts over cognition that occurs in very short periods of time, in milliseconds. Millisecond timing is heavily implicated in immediate behavioural responses, and these types of behaviour are of interest to those studying the core symptoms of ADHD. In particular it was questioned

whether findings of contextual sensitivity for cognition occurring over longer durations outlined in Chapter 1 could also be applied to cognition in the millisecond range. The findings of this thesis suggest that they can be. It was also questioned whether findings from research into social influences on cognitive processes such as problem solving can also be applied to individual behaviour in less overtly social settings? Once again, the findings of this thesis suggest that they can be.

Berry (1984) referred to several different types of context involved in research settings that interact with performance in different ways. The performance context, characterised by a specific and limited set of immediate environmental circumstances, was of particular interest for this thesis due to its influence over the immediate behavioural responses of children with ADHD. Therefore the particular features of the performance context require close scrutiny in order to examine possible explanations for sensitivity to contextual effects. This is explored in the following sections.

The experimental context was also of particular interest in this thesis as, according to Berry, it is determined by the environmental or task characteristics designed by the psychologist to elicit a particular response. Berry argued that this context also directly impacts on performance in terms of the behaviours that are recorded, measured or observed during testing. As sensitivity to contextual changes have been demonstrated close scrutiny of the environmental and task characteristics integral to the experimental design will also take place in this section.

In order to facilitate successful performance the literature outlined in Chapter 1 suggested that tasks ought to be made more meaningful and salient to children as contextual cues implicitly guide behaviour. Of particular interest was Ceci and Bronfenbrenner (1985) and Ceci (1990)'s finding that certain contexts help children to demonstrate abilities not generally seen in 'disembedded' laboratory contexts. They stated that:

‘For instance, if a task is perceived as a video game it may help recruit a set of strategies that children have acquired to conquer video games that might not be recruited if the same task is perceived as a type of test.’

(Ceci & Roazzi, 1994, p.77).

The potential impact on performance of the computer game playing context was the main focus of the empirical investigations that were conducted to examine the contextual sensitivity of children with ADHD. Importantly, Ceci and Bronfenbrenner’s findings were replicated in this thesis for children with a constitutional disorder .

Ceci and Roazzi (1994) were also extremely interested in the impact of context on cognition. The following statement was made by these researchers concerning the contextual sensitivity of typically developing children, however it is reported here as it seems particularly relevant for summarising the main findings of this thesis:

‘Can changes in the physical and social contexts of a task alter the strategies a child uses? The answer, as will be seen, is that it can. Moreover, one would have no reason to believe that children even possessed the strategy if they were evaluated in only one type of context.’

(Ceci & Roazzi, 1994, p.77)

The following sections therefore summarise in more detail the findings of the empirical work conducted to investigate the contextual sensitivity of children with ADHD and merge findings to discuss some of the main conclusions and implications.

10.3.1 The Questionnaire Studies: Studies 1 and 2.

From the outset findings indicated contextual effects on performance as the findings of Studies 1 and 2 confirmed the contrast between previous empirical findings and anecdotal evidence concerning the stability of problems of executive and inhibitory performance of children with ADHD. When playing computer games parents reported that children with

ADHD are able to behave in a way that suggests improved attention, concentration, ability to resist distractions, success at achieving and performing well and mental activity. In short they were reported to display abilities suggestive of improvements in inhibitory control. The primacy and pervasiveness of an inhibitory deficit in ADHD was questioned. Results hinted at context dependent changes in performance. Parental reports obtained in Study 2 indicated that children with ADHD are particularly interested in playing all types of games, but importantly, that a range of contextual features appears to contribute to this special interest. These features included specific characteristics of the game, such as level of stimulation, constant change in action, features such as sound and graphics, and the way in which the game was framed, for example whether there was the element of competition, the type of character used, the presence of a meaningful goal, and lack of negative feedback. Children with ADHD were reported to be particularly interested in games that are fast moving, colourful and interactive, furthermore, parents felt that such factors affected their child's success on computer games. Findings indicated that the use of character was important for children with ADHD but not so important for TD children, that meaningful goals influenced a child's interest in the game and that the element of control was a factor mentioned far more frequently by parents of children with ADHD.

Parental reports also suggested that an element of competition, or the presence of immediate feedback in the form of a score, influenced interest in computer games. The desire to beat scores was the second most frequently mentioned factor by both groups of parents in Study 2, where children were reported to keep playing in order to beat either others or their own old scores and were reported to be concerned with how successful peers or siblings were on the game.

In Study 2 parents of children with ADHD also reported that the types of games that their children like to play are often those that reflect activities they participate in daily life.

Once again this suggests that the context in which the task is set is important. It may be

that in the computer game playing context the child becomes more competent at favoured activities where they can use 'real world' knowledge to guide their performance.

Reports from parents gained in these two studies provided further support for cognitive energetic and motivational deficits in ADHD (Jennings *et al.*, 1997; Sanders, 1983; Sonuga-Barke 1994, 1995a, 1995b). These studies did not negate claims that there children with ADHD experience specific problems with their performance on tasks requiring a range of executive skills, but they suggested that there may be circumstances in which some of the problems they face may be overcome. For example, these parental reports may indicate that children with ADHD experience slower inhibitory processes rather than a lack of inhibition. Findings did not provide support for models such as that of Barkley's (1997a; 1997b) that describe a persistent deficit of inhibition. However, these studies presented a reflection of parental opinions and were not based on observations of the abilities and behaviour of children with ADHD whilst playing computer games.

10.3.2 Performance on the CPT II and Computer Tasks and Games: Studies 3-8.

The questionnaire studies therefore pointed to the need for further empirical exploration and direct observation of the abilities and behaviour of children with ADHD when playing computer games. In summary the results gained across the range of manipulations to the CPT in the series of subsequent studies also suggested that performance was context dependent. This was further emphasised by the observation that on commercially available games (Study 8) there were no differences between the performance of children with ADHD and TD children. These investigations also identified a clear distinction between different inhibitory processes. These were seen to be inter related but independent. There are several important implications concerning the impact of changes in task context that can be drawn from this. The following sections

outline some of the contextual features that may have impacted on performance. In general these contextual features appear to be the types of criteria that may help the child to make greater sense of the task, making it more meaningful, interesting and desirable. However, in particular there appeared to be a specific interaction between the contextual features of the computerised tasks and the physiological nature and cognitive and behavioural nature of ADHD.

10.3.3 Features of Computer Games

The failure to find any statistically significant differences between the proportion of errors produced on *Crash Bandicoot* compared to *Frogger* of both ADHD and TD participants suggested that both games contained similar features that affected performance. This may reflect the fact that both of these games have been designed to be commercially successful and therefore as interesting and motivating as possible by their manufacturers. Although *Crash Bandicoot* is the most recent and sophisticated in terms of graphics and game play the impulsive responding of all participants was equivalent on this game. This would suggest that there is something more than the visual and auditory characteristics, or ‘packaging’ of the game that are of importance in terms of performance enhancements. Perhaps the structure of the game, and its storyline, characters and goals are more important for performance. These features might certainly help to make the game ‘make sense’ to the player.

Much of the literature on the features of computer games stresses the importance of the motivational content of games. To reiterate, Reiber (1996) described games as intrinsically motivating, Amory *et al.* (1999) suggested that compelling graphics, sounds and narratives stimulates motivation. This appears to have been supported by findings of Study 8. The games used in Study 8 involved compelling graphics, narratives and complex and interesting sounds and inhibitory problems were not observed. Increased motivation has also been attributed to elements of novelty and complexity (Malone, 1984;

Malone & Lepper, 1987; Rivers, 1990), and fantasy and pretence (Malone, 1980; 1981a,b). All of these elements were present in *Crash Bandicoot* and *Frogger*. Findings of Study 8 may be accounted for by Malone's claims that elements of fantasy, curiosity and challenge make games fun, thus encouraging the child to expend more effort.

Malone also claimed that the most motivating games were those that had a specific goal to be achieved. This was a feature of both *Frogger* and *Crash Bandicoot*. Goals were to 'beat the level', to avoid losing lives, to score points, and to collect treasures. Both games were also unpredictable and challenging as they consisted of levels that increased in difficulty and multiple goal levels in the same environment. This meant that each participant was able to play at a level that was neither too easy nor too difficult. Malone claimed that this type of unpredictability and challenge is one of the most important motivational features of computer games.

10.3.4 Temporal Factors, Orchestration and Integration

Delay aversion theory suggests that inhibitory control is dependent upon temporal delay. When children with ADHD experience delay they exhibit delay averse hyperactive behaviour. Where no delay is required individuals with ADHD do not exhibit problems of inhibition. The results of Study 8 were consistent with this hypothesis. The games did not involve temporal delay, stimulation was constantly presented and the action presented on screen constantly changed and evolved as the child progressed through levels and no delay aversive behaviour was seen. It may be that the constant stimulation involved in the computer games was the key to inhibitory competence.

The difficulty in distinguishing between different types of temporally based errors proved to be the most controversial and problematic aspect of Study 8. Although the method for coding errors had been piloted using short samples of game play it became evident that such coding was more difficult for longer periods of game play. The main problem was the difficulty in distinguishing between errors of impulsive responding and errors

resulting from mis-timed moves. Impulsive errors clearly occurred when participants made a series of moves without stopping or hesitating. However, in some instances participants appeared to stop or hesitate but mis-timed their move so that a loss of life occurred. Where hesitation lasted for more than a couple of seconds it was clear that the error reflected either bad luck or poor timing of the next move. But problems in defining the error arose where hesitation was very brief. However, despite these difficulties inter-rated agreement was reasonably good.

The difficulty in distinguishing between errors of impulsive responding and errors of mis-timing emphasised the importance of accurate timing for inhibition. It highlighted the fact that inhibition is in part a temporally defined process and as such can be influenced by disruption of timing mechanisms. Difficulty in making the distinction between errors revealed that millisecond timing was crucial for an error to be defined as impulsive.

According to dual pathways models millisecond timing is implicated in the function of the meso-limbic branch that controls processing and interruption of habitual responding. (Nigg, 2000). The functioning of this pathway is said to be affected by motivational state (Nigg, 2000; Sonuga-Barke, 2002). Clearly therefore the dual pathway account predicts that inhibition of habitual responses (such as the ongoing response of pressing the spacebar) depends upon control of millisecond timing and can be affected by motivation. This was supported by the findings of Studies 3-7.

The ability to accurately time responses became more important in the computer game playing context where participants were required to respond in more complex ways to multiple stimuli presented simultaneously. Computer games require temporal anticipation, co-ordinated timing, co-ordinated motor responding and fast responses (Shewokis, 1997). This emphasises the importance of the integration of processes. This requires careful orchestration and timing (Brown, 1995; 1996; 1999; 2000). Brown disagreed with the insistence that inhibitory impairments are necessary for a diagnosis of ADHD. He proposed that the disorder is essentially one of dysregulation that affects all

executive processes and not just inhibition. Brown used the metaphor of a symphony conductor. Like the conductor the role of EF is to prioritise, integrate and regulate. Without the conductor the efforts of individuals are not integrated to produce a good sound. Similarly, without EF the efforts of the individual processes and systems are not integrated at the right time to produce successful performance. The performance of individuals with ADHD was therefore attributed to a problem of orchestration and timing. Brown proposed that the central feature of ADHD is an inability to activate and manage executive processes correctly, and at the right time. Brown suggested that the problem with the majority of research is that it looks at the performance of individual processes. He argues, however, that these are not impaired in themselves, but do not function to their full potential due to problems of orchestration. Brown hypothesised that those with ADHD are often able to display adequate functioning of any of the particular individual executive skills in certain situations. Like Sonuga-Barke (1994b), Brown (1999) proposed that this is especially true 'when engaged in certain favourite activities'. Questionnaire responses given in Study 1 revealed that computer games were listed frequently by parents of children with ADHD as one of the favoured activities of their children.

According to Brown's hypothesis the findings of studies 1-8 can be accounted for by the proposal that, when motivated, individuals with ADHD can engage competently in any executive skill, including inhibition. Poorer inhibitory performance seen on some tasks could be attributed to an orchestration deficit and poor integration of EFs resulting from lack of interest and stimulation. In instances of increased stimulation it appears as if EFs were integrated sufficiently to allow effective prioritisation, integration and regulation of processes, resulting in good inhibitory performance. In studies 3 and 8 performance in terms of error rates was equivalent to that of TD participants, providing further support for Brown's claims that in some instances children with ADHD can display competence and evidence of inhibitory ability.

10.3.5 Effort and Cortical Arousal

Executive and inhibitory processing is said to be dependent upon amount of effort invested in the task. It is well documented that on many tasks children with ADHD have significant problems with effortful processing (Ackerman *et al.*, 1986a; August & Garfinkel, 1990; Borcharding *et al.*, 1988). Research suggests that individuals with ADHD suffer from a lack of consistent effort, as highlighted by variability in responding on stop signal and Go-NoGo paradigms (Kuntsi, *et al.*, 2001; Oosterlaan & Sergeant, 1996). This is likely to be the result of deficient neurological stimulation, although it may also be a reflection of learned helplessness based on past failures (Kuntsi, *et al.*, 2001) or a combination of both of these factors. Effortful processing is said to be extremely sensitive to motivation and arousal (Borcharding *et al.*, 1988). Results of studies 3-7 implicate increased effort where performance improved. Increased motivation may have influenced an increase in effort and speed of the inhibitory process as discussed by Sanders (1983).

This was also suggested by Kuntsi *et al.*, (2001) who examined three of the main models of ADHD: the behavioural inhibition account; delay aversion; and working memory EF deficit model. Their findings indicated that children with ADHD were able to inhibit but that their inhibitory mechanisms were slower and more variable in function, that problems of working memory did not correlate with performance on tasks and that children displayed a delay aversive response style, choosing small and immediate rewards at the expense of larger delayed ones. However, after controlling for conduct problems this delay averse response style was not seen. Results across all tests were variable and largely context dependent. Kuntsi *et al.* concluded that the results consistently supported a state-regulation theory of hyperactivity, such as that proposed by van der Meere (1996) and Sergeant (2000).

van der Meere suggested that ADHD is characterised by a state of non optimal activation and effort. Inefficient processing occurs due to lack of energetic input. But increases in stimulation, motivation and effort can result in improved inhibitory processing. Sergeant (2000) suggested that these energetic deficits occur on three levels. Disinhibition was said to occur as a result of poor motor organisation arising from problems of energetic resources that fail to activate processing mechanisms. This is supported by the findings of studies 3-7. Problems of hyperactivity and disinhibition appeared to be related to non optimal activation or effort state. Results appeared to be dependent upon the nature of stimulation and motivation that the task invoked. In the initial questionnaire study parents reported that the situations in which their children with ADHD were more attentive and performed well were those that they were most interested in. These were computer games. Those games and tasks adapted to be more 'game like' consistently facilitated better inhibitory performance across the investigations conducted for this thesis.

10.3.6 Stimulation

The importance of stimulation and motivation for inhibition was also stressed by parental reports in Study 2. The most frequently listed factor contributing to the child's interest in playing computer games was constant stimulation. Many parents also listed the frequent change in action as an important factor. The finding that parents also believed that their children both enjoy and are more successful and attentive on fast games provides further support for the observation that for good inhibitory performance children with ADHD require increased levels of stimulation.

Antrop *et al.* (2000) described children with ADHD as stimulation seeking. This description could be applied to those children tested in Studies 3-8. Poor inhibition appeared to be dependent upon the level of stimulation that tasks provided. For the CPT II poor stimulation resulted in greater stimulation seeking behaviour as reflected by less on-task activity and more distracted and fidgety activity. The level of activity exhibited

on the CPT II was similar to that observed by Antrop *et al.* (2000) who used an adaptation of the same observation measure across a 15 minute delay where participants received no stimulation.

10.3.7 Motivation

Changes in motivation that impacted upon effort, activation and stimulation of under activated cortical and subcortical regions of the brain, were therefore implicated in the findings of Studies 1-8. Clearly motivation is dependent upon type and level of incentive and the value placed upon the incentive. Slusarek *et al.* (2001) noted that manipulation of incentives resulted in quite different effects on performance. This was the finding of Study 7. It has been observed that hyperactive children place a lot of value on achieving rewards and have showed signs of inflated motivation to gain incentives that resulted in impulsive and uncontrolled reactions (Ament, 1974; Layne & Berry, 1983; Ross & Ross, 1976). Over sensitivity to reward has also been said to explain impulsive behaviour. In situations requiring passivity where tangible rewards were offered, and children appeared too motivated to sit still (Campbell *et al.*, 1986). Layne and Berry (1983) concluded that motivation is a multiplicative product of expectancy for a reward and the value of that reward.

The findings of the studies therefore suggested that motivation improved neurological function on tasks such as the *Pokemon* task and *Simpsons* tasks, resulting in reduced impulsive error rates and increased on-task activity. These results suggested that the most effective manipulation made to the CPT II, for performance in terms of error making , was the addition of familiar, fun, cartoon characters. This finding corresponded to parental opinions (Study 2), the third most frequently listed factor said to contribute to interest in playing computer games was also character.

10.3.8 Intrinsic Motivation

Intrinsic motivation, triggered by internal task factors such as variety and challenge, is believed to improve interest and impact on task skill and performance (Koestner & McClelland, 1990). Amory *et al.* (1999) suggested that computer games stimulate motivation through compelling graphics, sounds and storylines. This was supported by findings of studies 2, 3, 7 and 8. Inhibitory problems were not observed on the games *Crash Bandicoot II* and *Frogger* (Study 8), both of which involved compelling graphics, narratives and complex and interesting sounds. The inclusion of a narrative, the *Pokémon* Task (Study 3) resulted in improvements in impulsive error making.

The results also suggested that intrinsically motivating factors may have had different effects on different inhibitory processes. The indications were that both motivation and inhibition are multifaceted constructs. The results emphasised the complexity of the effects of forms of motivation.

10.3.9 Extrinsic Motivation

Extrinsic motivation is thought to be stimulated by social or external influences as it is influenced by socially reinforced perceptions and expectations and is associated with feelings of pressure to succeed (Koestner *et al.*, 1991). Social factors will influence perceptions of challenge and competition, factors discussed by Malone (1980; 1981a, b) as particularly influential in making computer games fun. Interestingly it can be noted that on all modifications of the CPT II that included the points system, the majority of participants wanted to know how well others had done on the 'game' and often asked for the highest score. This was unfortunately not recorded. This highlights the importance of social factors on value judgements about the self, and effects of competition on motivation and eventually inhibitory performance. This also relates to the comments of parents made in Study 2.

This form of extrinsic motivation is thought to have had different effects on the two measures of inhibitory performance. For on-task activity, this may have resulted in the improvements seen in performance. But for impulsive error making it may have resulted in over arousal. Initially it was hypothesised that this may have been due to the extra visual stimuli presented with the task. However, the task with auditorally presented feedback (Study 6) produced the same results. This influence of social factors on the inhibitory performance of children with ADHD is relatively under investigated but is likely to contribute significantly to contextual effects on performance.

10.3.10 Degree of Incentive

The degree of incentive is likely to be essential in terms of effects on performance. Slusarek (2001) described how motivational state depends upon personal or dispositional (motive/strength) and situational (reinforcement) factors. Sonuga-Barke *et al.* (1992) acknowledged that delay aversive response style might be dependent upon failure of rewards to be meaningful or motivating. They report that children with ADHD:

might have waited if they had been choosing between small and large consumable rewards such as sweets or goes on video games

(Sonuga-Barke *et al.*, 1992, p.395)

10.3.11 Reinforcement

Barkley and others have suggested that poor inhibitory performance reflects a lack of sensitivity to reinforcement. Sonuga-Barke (1994b) and Schweitzer and Sulzer-Azaroff (1988) have also suggested that a preference for smaller immediate rewards reflects a desire to avoid delay and indifference to reinforcement. This theory was not supported by the findings of Study 7. Douglas and Parry (1983) suggested that individuals with ADHD are over sensitive to rewards. Some evidence to support this theory was found, with results suggesting that individuals with ADHD are sensitive to both reward and cost. These had different effects on inhibitory performance. Rewards and low levels of response cost improved on-task activity but not error making. This suggested over-

sensitivity to reward in terms of ability to inhibit an ongoing response. Increased desire to achieve rewards appeared to have distracted from the main aim of inhibiting impulsive responses. Participants appeared to respond as quickly and frequently as possible in order to try to gain rewards despite the fact this was likely to increase error making. In order to substantiate this claim it would have been necessary to note whether participants made more responses on the modifications of the CPT II. This was not recorded on these tasks, which only recorded whether or not a participant responded to each of the stimuli and not the amount of responses given to each stimulus. This information was however available from the data in Study 8, (in terms of error making on *Frogger* and *Crash Bandicoot II*), but in this study responding was equivalent for participants with ADHD and TD participants. A record of the exact number of responses might therefore be an interesting measure to incorporate into future studies of this kind.

Only where response cost was particularly high did impulsive error making improve. This directly contradicts the assumption of Douglas and Parry (1983) who described how too much negative feedback and loss of reward can cause poorer performance due to frustration. There are several possible reasons why this seemed unlikely. First, it may have been that the level of intrinsic motivation or drive facilitated better performance despite any level of frustration. Where response costs did not impact on error making this may have been due to their lower level rather than frustration. A higher level of response cost may have alerted participants to error making.

In summary results from the points versions of the CPT II suggested over sensitivity to gaining rewards, but under sensitivity to negative consequences, such as response cost. However, it is possible that this under sensitivity to response cost is only relevant where rewards are also present. Participants were sensitive to response cost and importantly this had the most significant effect on impulsive performance. But this occurred only where it

outweighed rewards. In short, rewards appeared to increase motivation and focus but response cost appeared to improve focus on error reduction.

10.4 Discussion

Analysis of Cognition: Implications for Models of ADHD

10.4.1 A Pervasive Deficit of Inhibition?

Contrary to models that attribute ADHD to core behavioural disinhibition, the findings reported in this thesis suggest that inhibition is an important, but not core, feature of ADHD. Although problems were seen in the ability to inhibit when completing the CPT II, these problems were reduced significantly when the CPT II was modified in certain ways. In contrast to the predictions of Barkley (1997b) the nature of the linear relationship leading from behavioural inhibition to other EFs and attention was not confirmed. Improvements were seen in the EFs said to be dependent upon behavioural inhibition despite lack of improvement in performance. For example, the ability to inhibit a prepotent response was not a pre-requisite for on-task activity. Participants displayed on-task attention despite poor impulse control and vice versa. The implication is that motivation, affect and arousal influenced inhibitory performance. This is in opposition to the claims of Barkley who suggested that improvements in inhibition must occur before improvements in self regulation of affect, motivation and arousal can occur.

10.4.2 Sensitivity to Environmental Cues: The BIS

An alternative argument is that under or over sensitivity to reward may reflect problems in detecting the signals for reinforcement, be they negative or positive. It is possible that individuals with ADHD fail to pick up on cues. This may be linked to attentional resources. Quay and colleagues proposed that failure of the BIS is due to reduced sensitivity to negative or novel environmental signals. Some support for this account was found in Study 7: when rewards were also present participants were less sensitive to

signals of non reward. Some support was also found for Jennings *et al.*'s (1997) claims that signals for inhibition activate CNS arousal that facilitates motor inhibition, anticipatory attention and preparation for responding. However, once again this only appeared to occur where signals for inhibition were made more salient than signals for activation. Motivation may have aided performance on the modified CPT II tasks by increasing the effort or resources allocated to search for signals or by making the signals that stimulated motivation more salient.

10.4.3 Delay Aversion

Sonuga-Barke's delay aversion account of ADHD proposed that behaviour is both context dependent and dependent upon motivation. Rather than a core deficit of inhibition, temporal factors and a motivation to avoid delay were hypothesised to be the cause of impulsive responses and behaviours. On the one hand, performance on the CPT II may be interpreted as evidence of delay aversive behaviour. However, Sonuga-Barke's model predicted that participants with ADHD will display hyperactive and impulsive behaviour across all conditions where delay is involved. This was not seen. Delay was equivalent across all modifications of the task and yet inhibitory performance was not. Furthermore no difference in performance was seen across the different inter stimulus intervals presented in the CPT II and *Pokémon* Task in Study 3. Despite the observation that participants exhibited a particular response style, where they responded quickly but inaccurately, on the CPT II, Short CPT II and Points Tasks, performance on the Points Tasks was accompanied by a greater degree of on-task activity. For all other manipulations of the task participants were able to inhibit more of these quick and inaccurate responses. The finding of increased error making was surprising considering that tasks involving the points system provided more immediate rewards in the form of either visual or auditory feedback.

10.4.4 Dual Pathways

The findings of Studies 3-7 highlighted a dissociation between inhibitory processes that lent support to dual pathways models of inhibition. There are several of these models, (Rapport *et al.*, 1999; Sonuga-Barke, 2002; Viggiano *et al.*, 2002) each of which identify inter related motivational and cognitive routes to inhibition. According to these models problems inhibiting an ongoing motor response, impulsive errors, can be attributed to dysfunction of the meso-cortical branch of the dopamine system. Hyperactive, distracted activity, lack of on-task focus, and an altered delay of reward gradient can be attributed to dysfunction of the meso-limbic dopamine pathway. The results from Studies 1-8 suggested that improved on-task activity occurred on activities and tasks that stimulated better functioning of the meso-limbic, 'motivational' dopamine pathway. This pathway is affected by reinforcement.

Alternatively, problems of impulse control are attributed to the deficit of the meso-cortical system responsible for motor control. This pathway appears to be harder to activate without the use of stimulant medication and it is not sensitive to reinforcement. This may account for the finding that improvements in impulsive error making were less consistent across tasks.

However, all of the dual pathways models proposed that both pathways are affected by stimulation. Some level of incentive appeared to have stimulated the pathways as improvements were seen for tasks that were fun, relevant to the child, challenging and visually stimulating.

The two pathways require different types of processing (Nigg, 2000). Whereas motivationally stimulated inhibition (the meso-limbic pathway) is automatically driven by immediate environmental signals and desire for reward, executive, cognitive inhibition (the meso-cortical pathway) is deliberately controlled and requires consistent attention and effortful processing. Importantly, Nigg (2000) argued that subcortical motivational

inhibition reacts by suppressing behaviour and cognition not directed at the triggering stimuli. This would help to explain why the addition of points improved on-task performance but impaired impulsive error making.

Rothbart and Bates (1998) also described executive inhibition as the deliberate, effortful control of behaviour and attention that develops as a result of functioning of anterior cortical structures. In contrast, motivational inhibition was described as a reactive process of behavioural interruption that relies on subcortical limbic structures.

Similarly, the Supervisory Attention System (SAS) model of disinhibition (Bayliss & Roodenrys, 2000) also attributed inhibitory control to the interaction of controlled and automatic processing pathways. Contention scheduling, (equivalent to Nigg's motivational inhibition and Sonuga-Barke's meso-limbic pathway) was described as an automatic, unconscious and resourcefully undemanding mechanism that controls responses to habitual or previously experienced events. This includes inhibition triggered by routinely encountered stimuli. In contrast, the SAS, (equivalent to Nigg's executive inhibition and Sonuga-Barke's meso-cortical pathway) was said to be a controlled, conscious and resourcefully demanding mechanism that interrupts habitual responses in the presence of novel or unexpected events. The SAS was said to be responsible for selection and orchestration of the most appropriate response.

10.4.5 A Disorder of Timing

Whereas long term timing is implicated for the meso-cortical dopamine pathway, short term, millisecond timing is implicated in the meso-limbic pathway. Timing of behaviours and cognition of both pathways is hypothesised to be impaired in ADHD. Of specific interest to this thesis was the influence context exerts over cognition that occurs in very short periods of time, in milliseconds. Results indicate that manipulation of task features and thus context had an impact on cognition that occurs in these short periods of time as demonstrated by performance in terms of error making on the modifications CPT. There

are few theoretical accounts of ADHD that implicate and comprehensively discuss timing (apart from the delay aversion theory of Sonuga-Barke, 1995, and to some extent that of Barkley, 1997). Poor motor inhibition in ADHD has been directly linked to timing (Capella *et al.*, 1977; Barkley *et al.*, 1997) and poor response inhibition has been associated with deficits of timing, especially time reproduction (Gerbing *et al.*, 1987; Montare, 1977; Pavlov, 1927). Deficits in timing can account for failure to identify the point at which to engage a behaviour and the fact that less inhibited individuals frequently under reproduce temporal durations (Barkley *et al.*, 2001; Gerbing *et al.*, 1987; Levine & Spivack, 1959; Levine *et al.*, 1959).

Such research has provided a brief indication of the timing abilities of children with ADHD. For example, individuals with ADHD appear to be able to estimate lengths of intervals that have passed but problems have occurred when they have been asked to estimate time as it happens (Barkley *et al.*, 1997; Capella *et al.*, 1977; Dooling & Litfin, 1997; Walker, 1982). Children with ADHD have exhibited problems producing intervals based on verbal or written information (Senior *et al.*, 1979; Walker, 1982; Capella *et al.*, 1977) and problems reproducing an interval they have previously experienced (Barkley *et al.*, 1997; Dooling & Litfin, 1997; Kerns *et al.*, 2001). Barkley *et al.*, (2001) reported that children with ADHD showed significantly more temporal discounting of rewards, choosing smaller but immediate rewards over larger delayed ones, and impairments on a time reproduction task than controls. These results were not associated with co-occurring ODD, delinquency or anxiety and depression.

However, these researchers may have overlooked the effects of the incentives given in these tasks. It is plausible that impulsive performance reflects lack of interest in the rewards offered. Other factors that might need to be investigated are the multi-directional nature of relationships between performance, timing and task demands. For example, although Barkley *et al.* (2001) considered task demands, suggesting that reproduction

tasks are the most resourcefully demanding tests as they take longer to process, they assumed that sense of time is dependent upon an attentional deficit. However, it is possible that attentional deficits are dependent upon sense of time or are inter-related due to a third deficit and yet Barkley *et al.* offered no discussion of this possible relationship. However, Barkley *et al.* (2001) recognised that variability in the performance of children with ADHD could have been the result of differences in CPT formats. This corresponds to the findings from Studies 3-7. The modifications made to the CPT by Barkley (1991) and Fischer *et al.* (1990) resulted in more commission errors, whereas modifications to the CPT II made in Studies 3-7 resulted in fewer errors. In direct contrast to the core deficit theory Barkley proposed in 1997, results in both instances can be attributed to contextual factors. In conclusion Barkley *et al.* (2001) suggested that good performance on time estimation tasks, where the delay has already occurred, suggested that both the perception of time and the capacity to co-ordinate a response relative to temporal standards and demands was impaired. This conclusion corresponds to Brown's (1999) observation that it is the ability to co-ordinate and orchestrate integration of processes within a temporal framework that is the core deficit of ADHD.

Furthermore, poor time reproductions and a tendency to overestimate duration by participants with ADHD were reported by Kerns *et al.* (2001) and Sonuga-Barke *et al.* (1998). A significant association was found between time reproduction and measures of impulsivity and inhibitory control. But working memory performance was not correlated with time reproduction performance (Kerns *et al.*, 2001). This contrasts directly with the claim of Barkley (1997a; 1997b) who attributed poor sense of time to working memory deficits. Sonuga-Barke *et al.* (1998) concluded that poor ability to estimate time as it elapsed was not due to poor ability to produce a strategy for representing time as all participants spontaneously used counting strategies. Nor was it likely to be due to an overly fast internal clock, because participants performed well when cues were given. The researchers suggested a misperception of time that was dependent upon task

demands. Where timing cues were not given the child was dependent upon their own timing ability. This focused attention on the perception of time and as a result may extend the subjective experience of time. Zakay (1992) also hypothesised that distractions further drain attentional resources and thus make the easily distractible, hyperactive child less aware of temporal information.

However, this type of research has largely failed to discuss the importance of timing and its relationship to cognitive and behavioural problems and how a deficit of timing might account for the variety of frequently complex and contradictory research findings.

Despite this under investigation timing may be one of the single most important factors implicated in the problems of ADHD. Timing facilitates prediction and anticipation of events, planning and preparation and orchestration of cognitive processes and behavioural responses. It is essential for motor control and response preparation and thus alertness and activation (Brandis *et al.*, 1998; Rubia *et al.*, 1999). Poor alertness and arousal will in turn affect effort.

Low concentrations of dopamine are implicated in the temporal integration of external cues and motor performance. Dopamine is said to be essential for ensuring both homeostasis and regulation, it allows integration of the different pathways. Timing in the millisecond range is hypothesised to be controlled automatically by an internal timing system (Paule *et al.*, 2000). This internal timing system is associated with the lateral cerebellum, vermis and suprachiasmatic nucleus of the hypothalamus, part of the limbic system. Once again, the claim is made that long term timing implicates cognitive processes of memory, planning and strategy choice. This is associated with a network that includes the basal ganglia and frontal cortex. It is the integration of these pathways that appears to be essential for attention, working memory, EF and in particular, inhibitory processing.

Thus the regions of the brain responsible for timing are those that provide the neural substrate for ADHD (Paule *et al.*, 2000). This provides further support for the claim that ADHD appears to be characterised by a deficit of timing. This may be the underlying factor that links the range and variety of problems seen in ADHD. This could also account for the complexity of cognitive and behavioural problems and dependency on contextual and situational factors. It is hypothesised that ADHD features a timing and orchestration deficit, resulting from neuroanatomical hypoarousal, reduced stimulation and activation dependent largely upon dopaminergic systems (Brown, 1999). This deficit would limit the interaction of critical systems such as the Supervisory Attentional System (SAS) (Baylis & Roodenrys, 2000), and the processes implicated in the dual pathways models. In the SAS model inhibition was attributed to a complex interaction between automatic contention scheduling and controlled assimilation of specific environmentally triggered responses.

The results of Studies 1-7 therefore suggest that the mechanisms responsible for interruption of ongoing automated responses, such as the SAS, are clearly dependent upon strict integration of temporally organised information. It is therefore possible that no single processes is consistently dysfunctional in ADHD, but that a range of problems exist and it is the ability to orchestrate, time and integrate these processes that affects performance at any given time in any given situation.

10.5 Conclusions

10.5.1 Summary

In conclusion there are several implications that arise from the findings of the studies reported in this thesis. These concern issues of epistemology and the importance of studying cognition in context. They also concern both theoretical and methodological approaches to understanding ADHD. ADHD, as a constitutional disorder, is thought to be characterised by deficits in executive function. Indeed, empirical research has supported

this claim and has indicated that children with ADHD experience specific types of inhibitory deficits. Consistent with these findings, many models describe ADHD as a disorder characterised by an executive deficit of inhibition. Some theorists have proposed that inhibitory dysfunction is the core characteristic of ADHD. This core deficit is said to give rise to the myriad of other cognitive impairments these children appear to experience. Others have argued that problems of inhibition are an important but not central feature of the disorder. These theorists have hypothesised that cognitive deficits are state or context dependent and are influenced by motivational and temporal features. In the studies reported in this thesis performance was measured in two ways. The first of these was error making, thought to reflect ability to inhibit an ongoing response and attention to task. The second was observations of time spent displaying on-task activity (ability to resist distraction and interference and to focus on the task in hand). The results of the studies implied that the processes responsible for inhibition of an ongoing, prepotent, response and on task attention may be inter-related but independently functioning processes. Improvements in one area were not necessarily accompanied by improvements in the other. This provided little support for core deficit theories of ADHD. Results from all studies suggested that performance was context dependent. Consistent with results from studies of social influences on cognition in context the performance of individuals with ADHD, in these more individual settings, appeared to depend on the framing of the task and its relevance and importance to the participant. Performance appeared to rely on the degree to which the task 'made sense' to the participant. The perceptions and interpretation that the participant placed on the context are potentially very significant for performance. This is likely to have had important implications for the affordances the individual attributed to the setting, and the degree to which the context increased motivation, stimulation, effort and arousal for activation of inhibitory mechanisms. Findings suggested that person variables, particularly motivation and

inhibitory ability are multifaceted constructs. Motivation was hypothesised to be both intrinsic and extrinsic. Intrinsic motivation was hypothesised to be affected by internal features of the tasks and games that made them fun, challenging but achievable. Such features included the addition of narratives, character and meaningful goals. Extrinsic motivation was hypothesised to be stimulated by more external features such as reinforcement and social expectations.

Although not directly measured the results suggested that intrinsic motivation influenced impulsive error making and that extrinsic motivation, promoted by reinforcement, influenced on-task activity. Reinforcement was also concluded to have had complex effects on performance. Rewards appeared to increase on-task activity but at the expense of accurate responding. The addition of small response costs did not appear to counteract this performance decrement. However, larger response costs were accompanied by significant reductions in impulsive error making. It was hypothesised that these larger response costs helped to draw attention to error making and prompt a more cautious response style.

The dichotomy observed between performance in terms of error making and on-task activity provided support for distinct meso-cortical (executive) and meso-limbic (motivational) pathways (Nigg, 2000; Rapport *et al.* 1999; Sonuga-Barke, 2002). These are a meso-cortical pathway responsible for control of motor responding, said to be dependent upon the function of nigrostriatal dopamine activity. And a meso-limbic, motivational pathway responsible for 'delay aversive' response style, motivation, response to rewards and sustained attention that is said to be dependent upon the function of mesocorticolimbic dopamine activity (Viggiano *et al.*, 2002). These pathways are hypothesised to be closely implicated in different timing mechanisms. The meso-cortical pathway in long term timing and the meso-limbic pathway in millisecond timing.

Timing was hypothesised to be particularly important for control of inhibitory processes. Deficient timing may give rise to, or significantly influence, the inhibitory performance of children with ADHD. Research suggests that mistiming, an altered perception of time and inability to recreate time characterise ADHD. It was concluded that poor orchestration and integration of processes dependent upon timing may give rise to the deficient functioning of the dual pathways in ADHD. This may stem from poor cortical arousal and lack of stimulation. This may be significantly influenced by contextual and situational variables.

Findings from all the studies in this thesis suggest that traditional measures of inhibition may not reflect competence. Children with ADHD were seen to perform as well as typically developing children when playing commercially available computer games in naturalistic settings. The findings also suggest that measures that attempt to extract single processes for controlled investigation may not provide much information about 'real world' functioning.

10.5.2 Future Considerations

There were several issues arising from Studies 1-8 that need to be identified and considered. First, each study used relatively small groups of participants, and included children with ADHD from all subtypes. In a replication of these investigations it would be interesting to investigate differences between hyperactive/impulsive, inattentive and combined subtypes. Furthermore, the impact of co-morbid disorder was examined by grouping all co-morbidities together and looking for possible interaction effects. This analysis was conducted due to the complex nature of combinations of co-morbidities (participants had unique combinations of co-morbid disorders). The analysis conducted was used to indicate whether further examination of the data was required. However, as a group the participants with co-morbid disorders did not perform differently to those without. However, there may be a single co-morbidity that does impact on performance.

Ideally it would therefore have been useful to recruit larger numbers of participants with each of the co-morbid disorders.

In addition it was difficult to recruit female participants with ADHD. This resulted in insufficient data to make gender based comparisons. This may reflect diagnostic trends. It may be the case that females with ADHD more commonly exhibit symptoms suggestive of the inattentive subtype. These symptoms are less disruptive and intrusive, and may therefore be under identified. This may account for lack of identification and diagnosis of females with ADHD. Alternatively it may be the case that ADHD is a genetic disorder predominantly inherited by males. However, the difficulty in recruiting female participants with ADHD may have some critical implications for the results of this study. The majority of participants with ADHD across all studies were male and this may significantly influence interest in computer games, and performance and behaviour while playing them. Research suggests that males tend to have more positive attitudes towards computers and higher levels of experience with computers than females (Whitley, 1997) and enjoy using computers in educational settings more than females (Janssen Reinen & Plomp, 1997). Light *et al.* (2000) argue that this is reflected by their greater interest in computers and computing courses across all levels of education. Furthermore, studies of collaborative learning and performance on computer based tasks have shown that boys dominate the control of the mouse and make more utterances, proposals, information seeking requests and repetitions than girls when completing computer based tasks in mixed gender pairs (Keogh *et al.*, 2000). Keogh *et al.* (2000) found support for Lee's (1993) view that such gender differences could be attributable to differences in perceived expertise, with boys seen as the experts (Joiner *et al.*, 1998).

In terms of Study 1, this might have explained why significantly more parents of children with ADHD signified that their child was particularly interested in computer games (significantly more male children in the ADHD group, 24 males, than the TD

group, 13 males). This could be a reflection of actual interest, perceived expertise or social influences on parental perceptions. However, this factor was ruled out after analyses showed no relationship between gender and interest in computer games in either the ADHD group (where all female participants were said to be interested in playing computer games, $p=.288$) or the TD group (where the majority of females were reported to be interested in playing computer games, $p=.825$). In Studies 3-6 comparisons between ADHD and TD groups were not made as all children were selected based on their interest and experience with computers and computer games. However the majority of participants were male, and male interest in computer games, or perceived expertise may have impacted on participants' desire to play the more 'game like' tasks particularly where points were available. Light *et al.* (2000) suggest that boys may be particularly driven by elements of challenge where there is a tacit expectation that details of their performance will be available to others.

Thus, without access to greater numbers of female participants it remains a possibility that performance on commercially available games and the more 'game like' tasks may have been affected by gender based interests and perceived ability on computer games. However, it must be noted that the interests of ADHD participants might also be affected by neuroanatomical differences in brain structure and function. Recently Baron-Cohen (2002) proposed that there are essentially five main 'brain types' that give rise to an individual's specific interests and abilities and to sex differences in interest and ability. These five types are determined by the degree to which the brain 'empathises' or 'systematises'. Individuals for whom empathising is more developed than systematising are said to have a female brain type. Those with a female brain type are said to be more interested in analysing or constructing information connected with people, relationships, emotions and thoughts. Individuals for whom systematising is more developed than empathising are said to have a male brain type. Those with a male brain type are said to be interested in analysing or constructing any form of system, whether technical, natural,

abstract, social, organisable or motoric and, importantly, computers fall within several of these systems. Individuals for whom both empathising and systematising are equally balanced are said to have a balanced brain type. And then there are the extremes of both the male and female brain types. Baron-Cohen suggests that individuals on the autistic spectrum fit the profile of having an extreme male brain type where systematising is hyper developed and empathising is hypo developed. Baron Cohen describes how individuals on the autistic spectrum are therefore 'drawn to predictable things, such as computers' (Baron-Cohen, 2000, pg 254). Significantly, there is often a great deal of similarity and overlap in the symptoms and behaviours exhibited by individuals with ADHD and those with autistic spectrum behaviours and there is a strong argument that the two disorders are closely inter-related. Such an explanation might also be applied to the interests of children with ADHD. This might possibly also explain the frequency of ADHD in males.

Last, it would have been useful to have had access to the expertise to re-engineer commercially available software so that controlled manipulations can be made in real real-life contexts.

The results of the investigations also pointed to a need for additional investigations that were not facilitated by the methodology employed. For example, the results suggested that the inhibitory processes of individuals with ADHD occur but are much slower where the context is not stimulating. It would therefore have been interesting to have had a measure of speed and duration of response. Mason and Redeker (1993) suggested that one way to achieve this is to use a technique known as actigraphy, this gives a recording of frequency, intensity and time of inhibitory responses.

One of the main assumptions made in the interpretation of results was that features of computer games were more motivating and increased level of stimulation. It would therefore have also been useful to have included a measure of motivation and stimulation.

Measures of motivation commonly rely on participant ratings. However, these are thought to be more representative of extrinsic motivation and are subject to external affective influence such as social influence. Measures of intrinsic motivation appear much harder to gain. Measures of stimulation could be equally problematic and suggest some degree of invasive procedure or physiological examination which was not available. By their nature these measurements would also have further distracted from the aim of making investigations as naturalistic as possible.

Other measures that would have been useful include the number of responses made to each stimulus. Douglas and Parry (1983) suggested that children with ADHD are oversensitive to rewards and that they over respond to reinforcers. Unfortunately these investigations only recorded accuracy of responding and whether or not a stimulus was responded to once, and not total number of responses. Many children with ADHD also appeared to want to know how well others had done or the top scores on tasks where points were involved. In order to examine the impact of competition it would have been useful to include a measure of social influence, to record and analyse the numbers of children who asked for top scores, or how well others had done, or to have compared performance where no indication of previous scores was given to performance when children were given an indication of the top score.

In addition it would have been interesting to have gained an idea of the relationship between motivation and perceived ability on each of the tasks. It was hypothesised that children are more motivated to perform well on tasks for which they perceive they can achieve a relatively good level of success. It may therefore have been useful to conduct informal interviews with the children both before and after testing.

In conclusion, the results of the present research suggest that inhibitory performance of participants with ADHD is context dependent. Real world contexts that were stimulating and fun promoted better inhibitory performance. Furthermore, the two aspects of

behavioural inhibition that were measured appeared to be differentially affected by the contextual factors manipulated. Impulse control appeared to be particularly sensitive to manipulations of task and game features such as narrative and character, whereas on-task activity appeared to be more sensitive to reinforcement strategies. The implications are that inhibitory ability, and indeed general cognitive performance, should be assessed in real world settings to gain a broader understanding of competence and thus the cognitive profiles of individuals with disorders such as ADHD. In addition, the findings suggest that in order to promote inhibitory performance of children with ADHD in daily settings tasks should be made as stimulating, fun, motivating and relevant as possible. The specific interest and competence exhibited by children with ADHD on computer games could be used to maximise their potential in other domains.

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Appendix 1

A

Questionnaire For Parents

This questionnaire has been designed to help ascertain whether there are certain activities in which children with Attention Deficit Hyperactivity Disorder show an interest and to which they attend and concentrate on for longer than they are able to in most other situations. Identification of the circumstances in which ADHD children can concentrate for longer and resist distractions could be important in helping these children concentrate and pay attention in other situations in which they may experience difficulties, such as the classroom.

The questionnaire is completely confidential. This is not a test of your child's abilities, it is simply a research tool for obtaining general information about the behaviours of children with Attention Deficit Hyperactivity Disorder.

Your participation is greatly appreciated, the views of parents are extremely important in guiding research in this area. Thank you for taking the time to complete the questionnaire.

Child with ADHD's full name _____

Address _____

Please complete this questionnaire with respect to your child with ADHD named above.

Q1. Child's date of birth? ____/____/____

Q2. Child's gender? ☐ Male ☐ Female

Q3. Has your child been diagnosed as having Attention Deficit Hyperactivity Disorder? ☐ Yes ☐ No

If Yes, has your child also been diagnosed as having a co morbid disorder in addition to ADHD, such as conduct disorder, dyslexia etc? ☐ Yes ☐ No

If Yes, what is this disorder? _____

And, in which year(s) was the diagnosis of ADHD made? _____

Q4. Is your child receiving medication for their ADHD? ☐ Yes ☐ No

If Yes, What is the name of the medication they are receiving? _____

Q5. Does your child have difficulties concentrating, sitting still and paying attention? ☐ Yes ☐ No
If Yes, does this occur: (please tick one of the following)

- a) most of the time ☐
- b) some of the time ☐
- c) in only a few situations ☐

Q6. When your child is asked to sit still and focus on a task please rate the degree to which they are distracted by the following:

Please tick one of the three boxes provided,
where 0 = not at all, 1 = somewhat, 2 = very.

- | | | | |
|---|-------------------------------|-------------------------------|-------------------------------|
| a) visual stimuli e.g. bright flashing lights, pictures etc. | 0
<input type="checkbox"/> | 1
<input type="checkbox"/> | 2
<input type="checkbox"/> |
| b) auditory stimuli e.g. music, radio, voices etc. | 0
<input type="checkbox"/> | 1
<input type="checkbox"/> | 2
<input type="checkbox"/> |
| c) visual and auditory stimuli combined e.g. television, video etc. | 0
<input type="checkbox"/> | 1
<input type="checkbox"/> | 2
<input type="checkbox"/> |
| d) objects or materials nearby e.g. toys or household objects etc. | 0
<input type="checkbox"/> | 1
<input type="checkbox"/> | 2
<input type="checkbox"/> |
| e) other people e.g. family members, friends, teachers, other adults etc. | 0
<input type="checkbox"/> | 1
<input type="checkbox"/> | 2
<input type="checkbox"/> |

f) other activities e.g. playing with toys, computer games, sports, other jobs etc. 0 1 2
☐ ☐ ☐

g) other, please describe _____ 0 1 2
☐ ☐ ☐

Q7. Does your child have problems sitting still and concentrating on one thing at a time?

Yes	No
-----	----

Q8. Are there particular circumstances in which your child finds it extremely difficult to concentrate on the task in hand?

Yes	No
-----	----

For the following circumstances please indicate the degree to which your child would find it difficult to concentrate on the task in hand by ticking one of the three boxes provided, where 0 = not at all, 1 = somewhat, 2 = very.

a) when doing activities in the classroom 0 1 2
☐ ☐ ☐

b) when doing academic activities at home, e.g. homework, reading, revision etc. 0 1 2
☐ ☐ ☐

c) when doing activities which are part of the daily routine, e.g. getting ready for school, mealtimes, getting ready for bed etc. 0 1 2
☐ ☐ ☐

e) other, please describe _____ 0 1 2
☐ ☐ ☐

Q9. Are there circumstances in particular in which your child finds it easier to concentrate on the task in hand?

Yes	No
-----	----

For the following circumstances please indicate the degree to which your child would find it easier to concentrate on the task in hand by ticking one of the three boxes provided, where 0 = not at all, 1 = somewhat, 2 = very.

a) when doing physical activities e.g. sports, bike riding, playing football, skateboarding, etc. 0 1 2
☐ ☐ ☐

b) when doing more passive, non physical activities e.g. watching television, videos etc. 0 1 2
☐ ☐ ☐

c) when doing quiet mental activities e.g. reading, solving puzzles etc. 0 1 2
☐ ☐ ☐

d) when playing computer / video / console games. 0 1 2
☐ ☐ ☐

e) other, please describe _____ 0 1 2
☐ ☐ ☐

Q10. Are there any circumstances in which your child shows a great deal of interest in an activity?

Yes	No
-----	----

If Yes, please list up to 3 such activities

1. _____
2. _____

3. _____

In these circumstances does your child

a) seem to be able to concentrate and focus on the task for longer than on most other activities?

Yes	No
-----	----

b) appear to perform better than on most other activities, i.e. are they successful at this activity?

Yes	No
-----	----

c) do they appear to overcome problems of impulsivity?

Yes	No
-----	----

d) do they appear to overcome problems of distractibility?

Yes	No
-----	----

Q11. Are there times when your child can sit still and concentrate on an activity?

Yes	No
-----	----

If yes, would you say that;

a) they are more motivated in this situation?

Yes	No
-----	----

b) they are more mentally active in this situation?

Yes	No
-----	----

c) they are less physically active in this situation?

Yes	No
-----	----

d) they stop and think more before acting in this situation?

Yes	No
-----	----

e) they ignore distractions more in this situation?

Yes	No
-----	----

Q12. Can you list the top three activities on which your child will concentrate for longer than on most other activities

1. _____
2. _____
3. _____

Q13. Are there certain times of day when your child is better at sitting still and concentrating?

Yes	No
-----	----

If yes, is this (please tick)

a) in the morning ☐

b) in the afternoon ☐

c) in the evening ☐

d) other (please name) _____

Q14. As a rule, will your child stop and wait for something that they like or want when asked to?

Yes	No
-----	----

Q15. As a rule, will your child do something you have asked them to do in order to gain something that they like or want?

Yes	No
-----	----

Q16. Does your child have access to computer/console/video games, e.g. at home, at a friend's, at school?

Yes	No
-----	----

If no, please go to question 23.

If yes, please go to the next question.

Q17. Does your child show an interest in playing computer/console/video games?

Yes	No
-----	----

If no, please go to question 23.
If yes, please go to the next question.

Q18. Please name the computer / console / video games which hold your child's attention?
(please list 3 games)

1. _____
2. _____
3. _____

Q19. When playing computer games does your child;

a) seem to be able to concentrate and focus on the task for longer than on most other activities?

☐ Yes ☐ No

b) appear to perform better than on most other activities, i.e. are they successful at this activity?

☐ Yes ☐ No

c) do they appear to overcome problems of impulsivity? ☐ Yes ☐ No

d) do they appear to overcome problems of distractibility? ☐ Yes ☐ No

Q20. When playing these games, would you say that your child is;

a) more motivated in this situation?

☐ Yes ☐ No

b) more mentally active in this situation?

☐ Yes ☐ No

c) less physically active in this situation?

☐ Yes ☐ No

d) stops and thinks more before acting in this situation?

☐ Yes ☐ No

e) is better at ignoring distractions in this situation?

☐ Yes ☐ No

Q21. If your child receives medication, does your child attend and concentrate on these games when they are not receiving their medication? ☐ Yes ☐ No

Q22. Are there any computer or console games which your child dislikes or rejects? ☐ Yes ☐ No

If yes, could you name up to 3 games?

1. _____
2. _____
3. _____

Q23. Would you have any objections to being contacted in the future during the course of this research?

☐ Yes ☐ No

Q24. Would you like to receive a summary of the questionnaire responses after the information has been collected? ☐ Yes ☐ No

Thank you again for taking the time to complete the questionnaire, your participation is greatly appreciated.

Appendix 2

B

Questionnaire For Parents

This questionnaire has been designed to help ascertain whether there are certain circumstances in which young children attend and concentrate for longer than in other circumstances. Identification of the circumstances in which young children can concentrate for longer and resist distractions could be important in helping these children concentrate and pay attention in situations in which they may have difficulties, such as the classroom.

The questionnaire is completely confidential. This is not a test of your child's abilities, it is simply a research tool for obtaining general information about the behaviours of young children.

Your participation is greatly appreciated, the views of parents are extremely important in guiding research in this area. Thank you for taking the time to complete the questionnaire.

Child's full name _____
Address _____

Please complete this questionnaire with respect to your child named above.

Q1.Child's date of birth? ___/___/___

Q2. Child's gender?

Male

Female

Q3. Does your child have problems concentrating, sitting still and paying attention?

Yes

No

If Yes, does this occur: (please tick one of the following)

- d) most of the time ☐
- e) some of the time ☐
- f) in only a few situations ☐

Q4. When your child is asked to sit still and focus on a task please rate the degree to which they are distracted by the following:

Please tick one of the three boxes provided,
where 0 = not at all, 1 = somewhat, 2 = very.

	0	1	2
a) visual stimuli e.g. bright flashing lights, pictures etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b) auditory stimuli e.g. music, radio, voices etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c) visual and auditory stimuli combined e.g. television, video etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d) objects or materials nearby e.g. toys or household objects etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e) other people e.g. family members, friends, teachers, other adults etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
f) other activities e.g. playing with toys, computer games, sports, other jobs etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
g) other, please describe _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q5. Does your child have problems sitting still and concentrating on one thing at a time?

Yes	No
-----	----

Q6. Are there particular circumstances in which your child finds it extremely difficult to concentrate on the task in hand?

Yes	No
-----	----

For the following circumstances please indicate the degree to which your child would find it difficult to concentrate on the task in hand by ticking one of the three boxes provided, where 0 = not at all, 1 = somewhat, 2 = very.

- | | | | |
|---|--------------------------|--------------------------|--------------------------|
| | 0 | 1 | 2 |
| c) when doing activities in the classroom | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| | 0 | 1 | 2 |
| b) when doing academic activities at home, e.g. homework, reading, revision etc. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c) when doing activities which are part of the daily routine, e.g. getting ready for school, mealtimes, | | | |
| getting ready for bed etc. | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d) when doing chores | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e) other, please describe _____ | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Q7. Are there circumstances in particular in which your child finds it **easier** to concentrate on the task in hand?

Yes	No
-----	----

For the following circumstances please indicate the degree to which your child would find it easier to concentrate on the task in hand by ticking one of the three boxes provided, where 0 = not at all, 1 = somewhat, 2 = very.

- | | | | |
|---|--------------------------|--------------------------|--------------------------|
| a) when doing physical activities e.g. sports, bike riding, playing football, skateboarding, etc. | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b) when doing more passive, non physical activities e.g. watching television, videos etc. | | | |
| | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c) when doing quiet mental activities e.g. reading, solving puzzles etc. | | | |
| | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d) when playing computer / video / console games. | | | |
| | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e) other, please describe _____ | | | |
| | 0 | 1 | 2 |
| | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Q8. Are there any circumstances in which your child shows a great deal of interest in an activity?

Yes	No
-----	----

If Yes, please list up to 3 such activities

1. _____
2. _____
3. _____

In these circumstances does your child

a) seem to be able to concentrate and focus on the task for longer than on most other activities?

Yes	No
-----	----

b) appear to perform better than on most other activities, i.e. are they successful at this activity?

Yes	No
-----	----

c) do they appear to overcome problems of impulsivity?

Yes	No
-----	----

d) do they appear to overcome problems of distractibility?

Yes	No
-----	----

Q9. Are there times when your child can sit still and concentrate on an activity?

Yes	No
-----	----

If yes, would you say that;

a) they are more motivated in this situation?

Yes	No
-----	----

b) they are more mentally active in this situation?

Yes	No
-----	----

c) they are less physically active in this situation?

Yes	No
-----	----

d) they stop and think more before acting in this situation?

Yes	No
-----	----

e) they ignore distractions more in this situation?

Yes	No
-----	----

Q10. Can you list the top three activities on which your child will concentrate for longer than on most other activities

1. _____
2. _____
3. _____

Q11. Are there certain times of day when your child is better at sitting still and concentrating?

Yes	No
-----	----

If yes, is this (please tick)

e) in the morning ☐

f) in the afternoon ☐

e) in the evening ☐

f) other (please name) _____

Q12. As a rule, will your child stop and wait for something that they like or want when asked to?

Yes	No
-----	----

Q13. As a rule, will your child do something you have asked them to do in order to gain something that they like or want?

Yes	No
-----	----

Q14. Does your child have access to computer/console/video games, e.g. at home, at a friend's, at school?

Yes	No
-----	----

If no, please go to question 21.

If yes, please go to the next question.

Q15. Does your child show an interest in playing computer/console/video games?

Yes	No
-----	----

If no, please go to question 21.
If yes, please go to the next question.

Q16. Please name the computer / console / video games which hold your child's attention?
(please list 3 games)

1. _____
2. _____
3. _____

Q17. When playing computer games does your child;

a) seem to be able to concentrate and focus on the task for longer than on most other activities?

☐ Yes ☐ No

b) appear to perform better than on most other activities, i.e. are they successful at this activity

☐ Yes ☐ No

g) do they appear to overcome problems of impulsivity?

☐ Yes ☐ No

h) do they appear to overcome problems of distractibility?

☐ Yes ☐ No

Q18. When playing these games, would you say that your child is;

a) more motivated in this situation?

☐ Yes ☐ No

b) more mentally active in this situation?

☐ Yes ☐ No

c) less physically active in this situation?

☐ Yes ☐ No

d) stops and thinks more before acting in this situation?

☐ Yes ☐ No

e) is better at ignoring distractions in this situation?

☐ Yes ☐ No

Q19. If your child receives medication, does your child attend and concentrate on these games when they are

not receiving their medication? ☐ Yes ☐ No

Q20. Are there any computer or console games which your child dislikes or rejects?
If yes, could you name up to 3 games?

☐ Yes ☐ No

1. _____
2. _____
3. _____

Q21. Would you have any objections to being contacted in the future during the course of this research?

☐ Yes ☐ No

Q22. Would you like to receive a summary of the questionnaire responses after the information has been collected?

☐ Yes ☐ No

Q23. Has your child ever been diagnosed as having any developmental disability?
If Yes, please name _____

☐ Yes ☐ No

**Thank you again for taking the time to complete the questionnaire, your
participation is greatly appreciated.**